MONOGRAPHS ON PULPS #69

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Monograph on Pulps #69 5/18/73

# M O N O G R A P H

# O N

# P U L P S

TR-72-1552-28

Submitted Under:
Contract No. FDA 72-104

May 18, 1973

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PULPS

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# PULPS

## Summary

Very little information is available on the metabolic and toxicologic aspects of pulps. Those studies which have been performed have been primarily concerned with the utilization of pulps for the feeding of livestock and with bagassosis.

Ferguson (12), in an investigation of the digestibility of wheat straw and wheat-straw pulp, determined that the treatment of wheat straw with NaOH increased its digestibility by sheep.

On the basis of 175-day feeding trials with 8 first-lactation Holstein cows, Ronning and Bath (38) concluded that dried beet pulp is fully equal to barley in the replacement of approximately 25% of the energy of a basal ration consisting of 70% alfalfa hay and 30% barley.

Khan et al. (27) conducted a 2 x 2 factorial experiment (133 days) to compare the efficiency of various percentages of rice straw, bagasse pulp, molasses, rice bran, cotton seed cake and rapeseed (toria) oil cake in the fattening of 12 old bullocks. No statistically significant differences were observed among the rations, all of which proved satisfactory in the fattening of the animals (27).

Bagassosis is a respiratory disease resulting from the inhalation of dust from dried bagasse (24, 32, 50). However, this affliction does not result from the bagasse fiber itself but is caused by some living matter attached to the bagasse (14, 15).

## Chemical Information

I. Nomenclature

A. Common Names

1. Pulps
2. Bagasse

B. Chemical Name

None

C. Trade Name

None

D. Chemical Abstracts Registry Number

None Available

II. Empirical Formula

Not Applicable

III. Structural Formula

Not Applicable

IV. Molecular Weight

Not Applicable

V. Specification

None

VI. Description

A. General Characteristics

Bagasse consists of the crushed remnants of sugarcane stalks from which the sugar-containing juices have been extracted. It varies in color but is generally a dirty-gray yellow to pale green. It is bulky and quite nonuniform in particle size. Physically, bagasse is composed of two distinct cellular constituents: the thick-walled, relatively long, fibrous fraction derived primarily from the rind and to a lesser degree from the fibrovascular bundles dispersed throughout the interior of the stalk, and a second pithy fraction derived from the delicate, thin-walled cells of the ground tissue or parenchyma of the stalk. The usual composition of bagasse from the mill is about 45% insoluble solids or crude fiber, 6% soluble solids, and the remainder moisture. The approximate compositions of Hawaiian whole bagasse, the fiber fraction, and the pith fraction are given in Table 1 found on the following page (26).

Four carbohydrates make up about 76% of the dry weight of beet pulp in essentially the following proportions: galactan, 6%; araban 20%; cellulose, 25%; and pectin, 25%. Protein, ash, acetyl, and other constituents make up the remainder (34).

The composition of the wheat straw and straw pulp used in the study by Ferguson are presented in Table 2 (12).

**Table 2.** *Composition of untreated straw and straw pulp (as percentage dry matter)*

| | Untreated straw | Straw pulp | | Untreated straw | Straw pulp |
|---|---|---|---|---|---|
| Ether extract | 1·05 | 1·13 | True cellulose* | 35·28 | 43·78 |
| Crude protein | 2·78 | 2·02 | Pentosans in cellulose | 18·93 | 20·09 |
| Ash | 7·47 | 6·94 | Furfuraldehyde | 5·73 | 6·59 |
| Lignin | 15·10 | 13·64 | Other carbohydrates | 13·66 | 5·81 |
| | | | | 100·00 | 100·00 |

* Norman & Jenkins's true cellulose.

B. Physical Properties

Not Applicable

C. Stability

No Information Available

## VII. Analytical Methods

Not Applicable

## VIII. Occurrence

A. Plants

Bagasse is obtained from sugar cane. The other pulps are obtained from the plants from which their names are derived.

B. Animals

None

C. Synthetics

None

**Table 1.** Chemical Analyses of Hawaiian Bagasse and Bagasse Fractions,[a,b] %

| Variety of sugarcane | Fraction | Solubility[c]: Ether | Solubility[c]: Alcohol and benzene | Solubility[c]: Hot water | Pentosans | Lignin | Holo-cellulose | Corrected alpha-cellulose | Ash[d]: Total | Ash[d]: $SiO_2$ | Ash[d]: $Fe_2O_3$ and $Al_2O_3$ | Ash[d]: Calcium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44-3098 | whole | 0.3 | 3.5 | 2.6 | 27.1 | 21.6 | 76.0 | 38.7 | 1.63 | 0.75 | 0.33 | 0.10 |
| | fiber | 0.08 | 1.6 | 0.43 | 27.7 | 22.0 | 76.9 | 42.5 | 0.63 | 0.39 | 0.06 | 0.05 |
| | pith | 0.2 | 2.5 | 1.6 | 28.7 | 21.5 | 76.8 | 35.3 | 2.09 | 1.04 | 0.39 | 0.14 |
| 37-1933 | whole | 0.4 | 4.7 | 2.2 | 27.3 | 19.4 | 76.8 | 38.3 | 1.25 | 0.67 | 0.19 | 0.07 |
| | fiber | 0.08 | 1.7 | 0.36 | 28.4 | 20.3 | 77.7 | 42.1 | 0.82 | 0.52 | 0.15 | 0.06 |
| | pith | 0.2 | 1.9 | 2.6 | 28.8 | 19.5 | 78.1 | 34.3 | 1.83 | 1.05 | 0.22 | 0.18 |
| 38-2915 | whole | 0.4 | 3.6 | 2.4 | 26.4 | 19.4 | 78.3 | 38.8 | 1.96 | 0.88 | 0.47 | 0.08 |
| | fiber | 0.14 | 1.8 | 1.4 | 27.9 | 20.0 | 79.6 | 43.3 | 0.71 | 0.36 | 0.13 | 0.06 |
| | pith | 0.3 | 1.7 | 2.3 | 28.7 | 19.3 | 79.4 | 36.4 | 2.36 | 1.08 | 0.44 | 0.28 |
| 32-8560 | whole | 0.15 | 4.6 | 2.7 | 25.8 | 20.6 | 75.2 | 36.5 | 1.77 | 0.74 | 0.34 | 0.20 |
| | fiber | 0.18 | 2.1 | 1.4 | 27.5 | 21.0 | 76.9 | 41.9 | 0.66 | 0.28 | 0.09 | 0.06 |
| | pith | 0.3 | 3.0 | 1.0 | 27.6 | 20.6 | 76.6 | 33.1 | 1.87 | 0.96 | 0.38 | 0.17 |

Courtesy of *The Journal of the Technical Association of the Pulp and Paper Industry.*

[a] All data are on a moisture-free basis.

[b] Methods for the determination of pentosans, lignin, holocellulose, and alpha-cellulose are empirical; therefore, the analyses do not total 100%.

[c] Solubility data are a measure of the wax, fat, and sugar content.

[d] Ash content is of interest if the bagasse is to be pulped.

D. Natural Inorganic Sources

None

## Biological Data

I. Acute Toxicity

No Information Available

II. Short-term Studies

Cattle

Using 8 first-lactation Holstein cows, Ronning and Bath conducted a feeding study to determine the nutritive value of dried beet pulp. For periods of 175 days the cows were maintained on a basal ration consisting of 70% alfalfa hay and 30% barley or a restricted basal ration supplemented with dried beet pulp to supply approximately 25% of the energy requirement. Milk production and body weight were monitored for the duration of the tests. The feeding of beet pulp was observed to be nutritionally equivalent to the feeding of barley (38).

Khan et al. conducted a 2 x 2 factorial experiment to compare the efficiency of various percentages of rice straw, bagasse pulp, molasses, rice bran, cotton seed cake and rapeseed (toria) oil cake in the fattening of old bullocks. Twelve bullocks were randomly assigned to 4 groups and maintained for 133 days on rations A-D, which are shown in Table I. The composition of these rations is shown in Table II and the results of the test are presented in Table III. The authors concluded that no statistically significant differences exist among the rations. They attributed the differences in performance of the various groups to differences in individuality in the animals (27).

TABLE I

*Bullock Fattening Rations*

| | Rations | | | |
|---|---|---|---|---|
| | *A* Lbs. | *B* Lb. | *C* Lb. | *D* Lb. |
| Rice straw | 40 | 30 | 25 | 15 |
| Bagasse pulp | .. | 10 | .. | 10 |
| Rice Bran | 20 | 20 | 25 | 25 |
| Cottonseed cake (undecorticated) | 10 | 10 | 12·5 | 12·5 |
| Rapeseed (*toria*) oil cake | 10 | 10 | 12·5 | 12·5 |
| Molasses | 20 | 20 | 25 | 25 |
| Ground limestone | 0·6 | 0·6 | 0·6 | 0·6 |
| Salt | 0·2 | 0·2 | 0·2 | 0·2 |
| Total | 100·8 | 100·8 | 100·8 | 100·8 |

TABLE II

*Assumed Composition of Ingredients and Rations*

| | *Dry Matter* % | *Dig. Protein* % | *T.D.N.* % | *Ca.* % | *P* % |
|---|---|---|---|---|---|
| Rice straw .. .. .. | 92·5 | 0·6 | 41·5 | ·19 | ·07 |
| Bagasse pulp .. .. .. | 90·3 | .. | 41·0 | .. | .. |
| Rice bran .. .. .. | 88·0 | 8·2 | 63·0 | ·14 | 1·36 |
| Undecorticated cottonseed cake .. | 92·0 | 18·0 | 63·8 | ·18 | ·52 |
| Rapeseed (*toria*) oil cake .. .. | 93·6 | 26·9 | 61·3 | ·93 | ·95 |
| Molasses .. .. .. | 74·0 | .. | 60·0 | ·66 | ·08 |
| Rations: | | | | | |
| A .. .. .. .. | 88·76 | 6·37 | 55·74 | ·947 | ·463 |
| B .. .. .. .. | 88·51 | 6·31 | 55·69 | ·928 | ·456 |
| C .. .. .. .. | 88·37 | 7·81 | 59·30 | ·986 | ·561 |
| D .. .. .. .. | 87.12 | 7·75 | 59·25 | ·967 | ·554 |

TABLE III

**Summary of Weight Gains and Feed Consumption of Bullocks**

| *Rations* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| Number of bullocks .. .. .. | 3 | 3 | 3 | 3 |
| Average initial weight .. .. .. | 775·3 | 744·3 | 693·6 | 741·0 |
| Average final weight .. .. .. ,, | 897·0 | 1036·0 | 827·3 | 889·0 |
| Days on feed .. .. .. .. ,, | 33 | 133 | 133 | [illegible] |
| Average total gain per bullock .. .. ,, | 121.7 | 291.7 | 133.7 | 148.0 |
| Average daily gain per bullock .. .. ,, | 0·91 | 2·91 | 1·05 | 1·11 |
| Feed required per 100 lb. gain .. .. ,, | 2472·8 | 1240·2 | 2114·8 | 2160·4 |
| Average daily feed per bullock .. .. ,, | 22·6 | 27·2 | 21·2 | 42·4 |
| Rice straw daily .. .. .. .. ,, | 8.96 | 8.09 | 5.27 | 3.66 |
| Bagasse pulp daily .. .. .. ,, | .. | 2·69 | .. | 2·44 |
| Cottonseed cake daily .. .. .. ,, | 2·24 | 2·69 | 2·63 | 3·05 |
| Rapeseed (*toria*) oil cake daily .. .. ,, | 2·24 | 2·69 | 2·63 | 3·05 |
| Molasses daily .. .. .. .. ,, | 4·48 | 5·38 | 5·27 | 6·10 |
| Limestone daily .. .. .. .. ,, | 0·13 | 0·16 | 0·12 | 0·44 |
| Salt daily .. .. .. .. ,, | 0·4 | 0·5 | 0·4 | 0·4 |

## III. Long-term Studies

None

## IV. Special Studies

<u>Bagassosis</u>

Bagasse disease, or bagassosis, is a respiratory disease resulting from the inhalation of dust from dried bagasse. It is characterized by cough, dyspnea, and hemoptysis, night sweats, chills and intermittent fever. Roentgenologic examination of the chest shows molting of both lungs. The disease commences insiduously and the pulmonary reactions incited are reversible (24, 32, 50).

On the basis of their experiments, in which rabbits were treated, intravenously and intratracheally, with untreated and sterilized bagasse and 5 different micro-organisms isolated from bagasse, Gerstl et al. concluded that the bagasse fiber itself is a rather inert material and that the acute inflammatory process caused by bagasse is due to micro-organisms, probably fungi, attached to the bagasse (14).

A later study by Gerstl et al. confirmed their earlier statement regarding Bagasse Disease. In rabbits they found that a longstanding foreign body reaction results from bagasse fiber itself while some living matter attached to bagasse produces the acute inflammatory reaction. For the rabbit an Aspergillus is the pathogenic agent (15).

## Biochemical Aspects

I. Breakdown

No Information Available

II. Absorption - Distribution

The digestibilities of straw constituents in wheat straw and wheat straw treated with sodium hydroxide solution (straw pulp) were determined by Ferguson on sheep. The composition of the two products is presented in Table 1 and the digestibility coefficients of the straw constituents are presented in Table 2. The alkali treatment resulted in a marked increase in the digestibility of all constituents except lignin, which was totally indigestible (12).

**Table 1.** *Composition of untreated straw and straw pulp (as percentage dry matter)*

| | Untreated straw | Straw pulp | | Untreated straw | Straw pulp |
|---|---|---|---|---|---|
| Ether extract | 1·05 | 1·13 | True cellulose* | 35·28 | 43·78 |
| Crude protein | 2·78 | 2·02 | Pentosans in cellulose | 18·93 | 20·09 |
| Ash | 7·47 | 6·94 | Furfuraldehyde | 5·73 | 6·59 |
| Lignin | 15·10 | 13·64 | Other carbohydrates | 13·66 | 5·81 |
| | | | | 100·00 | 100·00 |

* Norman & Jenkins's true cellulose.

**Table 2.** *Average digestibility coefficients of the straw constituents*

| Constituent | Untreated straw | Straw pulp | Constituent | Untreated straw | Straw pulp |
|---|---|---|---|---|---|
| Dry matter | 47·8 | 63·8 | Lignin | 10·2 | −0·5 |
| Organic matter | 51·8 | 68·5 | Crude cellulose | 62·4 | 87·7 |
| | | | True cellulose | 62·1 | 86·7 |
| Ether extract | 43·7 | 40·9 | Pentosans in cellulose | 63·2 | 89·7 |
| Fibre | 60·3 | 81·0 | Furfuraldehyde | 51·2 | 84·2 |
| N-free extractives | 46·8 | 63·1 | Other carbohydrates | 67·0 | 76·9 |

III. Metabolism and Excretion

No Information Available

IV. Effects on Enzymes and Other Biochemical Parameters

No Information Available

V. Drug Interaction

No Information Available

VI. Consumer Exposure Information

No Information Available

PULPS

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# 89. The Digestibility of Wheat Straw and Wheat-Straw Pulp

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(*Received 3 August 1942*)

The digestion of straw constituents and cellulose by ruminants was the subject of a recent paper by McAnally [1942]. By means of in vitro and also in vivo experiments, using a sheep with a rumen fistula, she examined the rate of digestion of straw, straw constituents and cellulose. In the in vivo tests small quantities (0·5 g.) of the materials were tied in small silk squares and suspended in the sheep's rumen. McAnally states: 'it is probable that the conditions of digestion in the bag were not as favourable as in the rumen, so that the observed rates of digestion must be regarded as minimal.' The results showed that straw fractions such as cellulose and hemicelluloses were more digestible when separated than when fed in straw form.

A proportion of the straw resists digestion regardless of time, but McAnally thinks that too rapid progress through the rumen can cause considerable wastage and suggests some form of predigestion in vitro to eliminate this.

The digestibility of straw soaked for 24 hr. in 1·5% KOH and then thoroughly washed was also investigated, and a marked advantage over untreated straw was obtained. During the first 2 days in the rumen the digestion of the treated straw was no greater than that of untreated straw, and it is concluded that 'wastage through too rapid a passage out of the rumen may not be avoided by the alkali pretreatment'. The digestibility of the lignin in the alkali-treated straw was 71% as compared with 30% in the untreated straw.

Investigations on the alkali treatment of straws to increase their feeding value were commenced at Jealott's Hill in 1938, and in 1940, in view of the inadequacy of the conventional foodstuffs analysis, a trial was made to determine the digestibility of the true straw constituents. The results showed that the digestibility of the cellulose of alkali-treated straw was very high and they suggested that wastage, if any, by too rapid progress through the rumen must be quite small. They also suggest that the technique of McAnally does result in slower rates of digestion than that which occurs normally in the rumen.

The data presented here give only the fate of the various straw fractions during passage through the animal, or the total digestibility as understood in agricultural circles.

## Experimental

A uniform sample of good quality wheat straw was used throughout the trials. It was chopped to half-inch lengths and well mixed.

*Alkali treatment.* The chopped straw was immersed in 1·5% NaOH for 22 hr. at 10–15°, using 10 times the straw weight of solution. At the end of the time, the straw was removed from the liquor and after draining for 30 min. was thoroughly washed with water to remove the excess NaOH. The straw lost 20% of its dry weight in this treatment. For convenience the resulting material was called 'straw pulp'.

*Composition.* The untreated straw and the straw pulp were dried at 98°, ground and analysed by the standard feedingstuffs methods, and also in greater detail. Cellulose was determined by the method of Norman & Jenkins [1933] and also by that of Kürschner & Hanak [1930] as used by Crampton & Maynard [1938], the cellulosan fraction of the crude cellulose being determined by distillation with 12% HCl. Lignin was determined by the method of Ritter, Seborg & Mitchell [1932] as modified by Norman [1934]. The



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total furfuraldehyde yield was obtained by distillation with 12% HCl and subsequent precipitation as the phloroglucide.

*Digestibility.* Digestibility trials were carried out on sheep. Six sheep were used in each trial, the same sheep being used for both materials. The rations consisted of 600–700 g. of straw dry matter and 100 g. casein to supply protein. Rock salt and steamed bone flour were also provided. The straw pulp was naturally fed in the wet state. After a preliminary period of 4 days the faeces were collected daily for 10 days.

## RESULTS

### *Composition*

The standard feedingstuffs analysis is not given here in detail and it need only be stated that the crude fibre fraction which was 42·4% of the dry matter in the untreated straw and 51·5% of the dry matter in the straw pulp consisted of 90–93% crude cellulose and 7–10% lignin. The more detailed composition of the straws is given in Table 1.

Table 1. *Composition of untreated straw and straw pulp (as percentage dry matter)*

| | Untreated straw | Straw pulp | | Untreated straw | Straw pulp |
|---|---|---|---|---|---|
| Ether extract | 1·05 | 1·13 | True cellulose* | 35·28 | 43·78 |
| Crude protein | 2·78 | 2·02 | Pentosans in cellulose | 18·93 | 20·09 |
| Ash | 7·47 | 6·94 | Furfuraldehyde | 5·73 | 6·59 |
| Lignin | 15·10 | 13·64 | Other carbohydrates | 13·66 | 5·81 |
| | | | | 100·00 | 100·00 |

* Norman & Jenkins's true cellulose.

The analysis accounts for most of the dry matter in the straws. In the untreated straw 13·7% was undetermined and has been called 'other carbohydrates'. This fraction presumably consists mainly of carbohydrate material of more simple constitution than cellulose, and was evidently partly soluble in the NaOH. Only traces of reducing sugars were present. The furfuraldehyde fraction represents the hemicelluloses excluding the cellulosan fraction of the cellulose and some doubt exists as to the correct method of expressing the yield. Some workers convert the yield of furfuraldehyde into pentosans which increases the value by about 70%, but Norman [1937] thinks the more accurate way is to leave the fraction expressed as furfuraldehyde.

The most noticeable differences between the straws are the higher cellulose and lower 'other carbohydrate' contents of the straw pulp.

The analytical data clearly showed the mixed nature of the crude fibre and N-free extractives of the standard feedingstuffs analysis. The crude fibre consists mainly of cellulose from which a considerable part of the cellulosan has been removed, and some lignin. The N-free extractives are made up of part of the lignin, part of the cellulosan, the furfuraldehyde-yielding substances and 'other carbohydrates'.

The cellulose contents of the straw were also determined by the method of Kürschner & Hanak [1930]. It will be seen from Table 2 that this method gives a lower yield of crude cellulose than Norman & Jenkins's [1933] method, owing to the loss of a considerable part of the cellulosan fraction.

Table 2. *Cellulose contents of untreated straw and straw pulp. Comparison of methods (as percentage dry matter)*

| | Untreated straw | | Straw pulp | |
|---|---|---|---|---|
| | N. and J.* | K. and H.† | N. and J. | K. and H. |
| Crude cellulose | 54·21 | 39·45 | 63·87 | 52·18 |
| True cellulose | 35·28 | 35·00 | 43·78 | 43·81 |
| Pentosan | 18·93 | 4·45 | 20·09 | 8·37 |

* Norman & Jenkins's method. † Kürschner & Hanak's method.

*Digestibility*

The faeces of the sheep were analysed in the same way as the straws. It is interesting to note that the crude fibre in the faeces of the sheep receiving untreated straw consisted of 86% cellulose (almost entirely true cellulose) and 14% lignin, whereas in the case of the straw-pulp faeces the crude fibre contained 60% true cellulose and 40% lignin. These proportions are quite different from those found in the fibres of the original materials fed and show the unreliability of the crude fibre digestibility figures. It follows, therefore, that the digestibility value for the N-free extractives are also unreliable.

The average digestibility coefficients are given in Table 3 and the values for the individual sheep in the Appendix. The digestibility of the crude protein was ignored since this constituent forms a very small part of the whole.

Table 3. *Average digestibility coefficients of the straw constituents*

| Constituent | Untreated straw | Straw pulp | Constituent | Untreated straw | Straw pulp |
|---|---|---|---|---|---|
| Dry matter | 47·8 | 63·8 | Lignin | 10·2 | −0·5 |
| Organic matter | 51·8 | 68·5 | Crude cellulose | 62·4 | 87·7 |
| | | | True cellulose | 62·1 | 86·7 |
| Ether extract | 43·7 | 40·9 | Pentosans in cellulose | 63·2 | 89·7 |
| Fibre | 60·3 | 81·0 | Furfuraldehyde | 51·2 | 84·2 |
| N-free extractives | 46·8 | 63·1 | Other carbohydrates | 67·0 | 76·9 |

It is clear that the alkali treatment raised the digestibility of most of the constituents. The digestibilities of the true cellulose and pentosans in cellulose run parallel and therefore, the sum of these constituents, namely the crude cellulose, only need be considered. Its digestibility was raised from 62·4 to 87·7% by the treatment. The furfuraldehyde-yielding substances also increased markedly in digestibility. The 'other carbohydrates' showed a less marked increase, as might be expected from the nature of this fraction. The average digestibility of the lignin in the untreated straw was 10·2%, the range in the individual sheep being 4·4–16·6%. In the straw pulp a figure of −0·5%, or total indigestibility was obtained, the range being −9·1 to 6·4%. It can only be assumed that the treatment with alkali removed a part of the lignin which possessed some slight digestibility. It must be remembered, however, that the determination of lignin cannot be considered altogether reliable and appreciable errors could be introduced in this way.

## Discussion

During the passage of straw pulp through the sheep, approximately 70% of the dry matter and 90% of the cellulose were digested. This was quite efficient digestion and it occurred in a probable maximum of 3½ days. It seems unlikely that the food remained in the rumen for more than 2–2½ days. It is generally thought that in ruminants practically all the cellulose digestion or fermentation occurs in the rumen and the work of Trautmann & Asher [1939] certainly confirms this. The present work therefore cannot support McAnally's view that wastage by too rapid passage through the rumen might occur with straw pulp. It is interesting to note that McAnally obtained a figure for the digestibility of true cellulose of 88·8% by suspending straw pulp in the rumen for 7 days. This is very close to the value of 86·7% obtained for complete digestion in the present work. This also suggests that McAnally's technique gives a rate of digestion which is considerably slower than that occurring normally in the rumen.

The lignin appears quite indigestible in straw pulp and this does not agree with McAnally's findings. She obtained 70% digestibility of this constituent in the rumen and two possible explanations of the difference might be put forward. Either the lignin is considerably digested or rendered soluble in the rumen and then later deposited in some other part of the alimentary tract, or the difficulty in dealing with small quantities of material in the rumen fistula has introduced some error.

The digestibility data, which are typical of many obtained at Jealott's Hill, clearly show the benefit derived from the alkali treatment of straw. The increase in digestibility has the effect of approximately doubling the feeding value of good wheat straw to the ruminant.


## Summary

The digestibilities of straw constituents in wheat straw and wheat straw treated with sodium hydroxide solution (straw pulp) have been determined on sheep.

The alkali treatment results in a marked increase in the digestibility of all constituents except lignin. The lignin was totally indigestible.

Owing to the high digestibility of the major straw-pulp constituents, it is unlikely that any wastage occurs owing to too rapid passage of the material through the rumen.

The inadequacy of the conventional feedingstuffs analysis is discussed briefly.


The author wishes to thank Dr S. J. Watson for his interest in the work and the Directors of Imperial Chemical Industries Ltd., for permission to publish the results.

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## APPENDIX

*Digestibility coefficients*

| Sheep ... | 7 | 8 | 9 | 10 | 11 | 12 | Average |
|---|---|---|---|---|---|---|---|
| Untreated straw: | | | | | | | |
| Dry matter | 43·7 | 47·1 | 47·0 | 47·5 | 49·0 | 52·4 | 47·8 |
| Organic matter | 48·0 | 50·7 | 51·1 | 51·0 | 53·3 | 56·6 | 51·8 |
| Ether extract | 36·4 | 59·3 | 43·5 | 47·7 | 34·9 | 40·2 | 43·7 |
| Crude fibre | 57·8 | 58·6 | 55·5 | 60·2 | 63·1 | 66·3 | 60·3 |
| N-free extractives | 42·3 | 46·2 | 46·9 | 45·7 | 48·0 | 51·6 | 46·8 |
| Lignin | 4·4 | 13·9 | 10·5 | 6·0 | 9·8 | 16·6 | 10·2 |
| Crude cellulose | 60·0 | 60·4 | 59·9 | 62·4 | 64·9 | 67·0 | 62·4 |
| True cellulose | 59·9 | 59·6 | 60·2 | 62·2 | 63·9 | 66·5 | 62·1 |
| Pentosans in cellulose | 60·3 | 62·0 | 59·4 | 62·9 | 66·7 | 67·9 | 63·2 |
| Furfuraldehyde | 45·3 | 55·3 | 56·5 | 50·0 | 45·2 | 54·8 | 51·2 |
| Other carbohydrates | 60·6 | 60·4 | 69·7 | 66·8 | 71·2 | 73·3 | 67·0 |
| Straw pulp: | | | | | | | |
| Dry matter | 66·5 | 61·1 | 61·5 | 60·0 | 67·3 | 66·1 | 63·8 |
| Organic matter | 71·4 | 65·3 | 65·8 | 64·9 | 72·6 | 70·9 | 68·5 |
| Ether extract | 49·2 | 40·3 | 25·6 | 33·9 | 50·0 | 46·1 | 40·9 |
| Crude fibre | 83·6 | 77·0 | 80·2 | 78·3 | 83·9 | 82·9 | 81·0 |
| N-free extractives | 66·1 | 61·9 | 58·9 | 59·2 | 67·4 | 65·1 | 63·1 |
| Lignin | 4·4 | −1·1 | −9·1 | −6·1 | 6·4 | 2·8 | −0·5 |
| Crude cellulose | 90·6 | 84·1 | 86·0 | 85·0 | 90·6 | 89·7 | 87·7 |
| True cellulose | 89·7 | 82·5 | 85·0 | 84·3 | 89·9 | 88·7 | 86·7 |
| Pentosans in cellulose | 92·6 | 87·1 | 88·0 | 86·5 | 92·3 | 91·8 | 89·7 |
| Furfuraldehyde | 84·3 | 81·2 | 83·8 | 85·4 | 85·2 | 85·0 | 84·2 |
| Other carbohydrates | 75·9 | 77·3 | 81·4 | 68·8 | 81·6 | 76·2 | 76·9 |

# PATHOGENICITY OF BAGASSE

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SUGAR CANE from which the sugar content has been extracted is called bagasse. This material is stored in the open for months and even years; then it is broken, processed and finally pressed into various shapes yielding building and insulating boards, such as "celotex." Workers breaking bagasse sometimes acquire a respiratory disease characterized clinically by cough, dyspnea, occasional hemoptysis, night sweats, chills and intermittent low fever. Roentgenologic examination of the chest shows miliary mottling throughout both lungs in almost all cases. Most of the patients recover after prolonged illness. Although extensive clinical studies have been carried out, and in 1 case autopsy,[1] uncertainty still prevails as to the genesis of this disease.

In the opinion of Sodeman and Pullen [2] the etiologic agent and the mechanism of the changes are obscure, while Jamison and Hopkins [3] have expressed the belief that micro-organisms, probably fungi, growing on and causing deterioration of the fibers, and inhaled with these, cause the disease. Castleden and Hamilton-Paterson,[4] on the basis of positive cutaneous reactions obtained with extracts of bagasse, interpreted the disease as an allergic reaction. LeMone, Scott, Moore and Koven [5] in a recent report attributed the changes to the high silica content of the bagasse fiber.

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**Arch. Path. 44(4):343-349. 1947**

Attempts to reproduce the disease in animals were reported as unsuccessful.[2]

The present investigation was undertaken to determine experimentally the pathogenic properties of bagasse fibers and of the microbial contents of representative suspensions. The possibility that other factors, such as hypersensitivity, play a role in the development of the experimental disease was also explored.

## MATERIAL AND METHODS

Five lots of bagasse were obtained by courtesy of Dr. W. H. Reinhart, of the Louisiana State Department of Health. These were arbitrarily called A, B, C, D and E. Lots A and E were employed for these experiments. Lot A had been baled in January 1944 and stacked for two years. Lot E was a sample of dust collected from rafters near the conveyer in a bailing shed.

For experimental intravenous injections, bagasse was ground in a Waring blender, sterile saline solution added and the suspension filtered through sterile cheesecloth. The suspended particles varied in size from less than 1 micron to 15 microns. They were counted in a hemocytometer, and the suspension was adjusted so that 7,500 particles were present in a cubic millimeter. For intratracheal application, suspensions containing 30,000 to 35,000 particles per cubic millimeter of a size up to 100 microns were made up.

Rabbits and guinea pigs of similar weights and ages were employed in the experiments.

## RESULTS

*Intravenous Administration.*—Rabbits receiving intravenous injections of a suspension of bagasse A (5 doses of 5 cc. each at three day intervals) rapidly became sick, listless and dyspneic and showed paralysis of the hindlegs. One of them died on the third day, and the three remaining animals were so sick that they were killed on the fourth day. When, however, an aliquot of the bagasse suspension was autoclaved (twenty minutes at 15 pounds [6.8 kg.] of pressure) similar amounts could be given without any apparent ill effect. For control purposes, 2 animals given the autoclaved suspension were killed at an interval corresponding to that of deaths in the first group. The lungs and parenchymatous organs of the animals given the fresh bagasse suspension showed extensive foci of necrosis and marked cellular reaction (fig. 1), indicating that this suspension contained a powerful pathogenic agent. The presence of mycelia and spores (fig. 2) in the organs showing the severest damage served as a clue to the nature of the agent. It is noteworthy that similar lesions could be produced by a single injection of a more concentrated suspension.

In contrast, preparations representing the rabbits given injections of the autoclaved bagasse suspension revealed only small granulomatous lesions of the foreign body type in the lung (fig. 3). Necrosis was absent, and the other organs were free of lesions.

It was then established that autoclaved bagasse suspensions could be given repeatedly without any adverse effect. A rabbit that received 16 intravenous injections, totaling 74.5 cc., over a period of thirty-nine days was killed thirty-eight days after the last injection. Lesions were not seen grossly or microscopically except for an occasional small group of monocytes containing small, irregularly shaped foreign bodies, noted in sections of the lung.

These results suggested that one or several types of micro-organisms present in the bagasse were the pathogens, while the fiber itself under the conditions tested produced only a foreign body reaction of no apparent consequence to the experimental animal.

In the bacteriologic studies five different micro-organisms were isolated from bagasse A suspension and cultured on various mediums under aerobic conditions: Organism 1 gave the reactions of the group of organisms designated bacteriologically as Bacillus polymyxa. Organism 2 was a characteristic form of Aspergillus fumigatus. Organism 3 was an aerobic member of the Actinomyces group. Organism 4, while differing i.. gross appearance from 2, showed microscopic characteristics that place it in the Aspergillus fumigatus group also. Organism 5 was an aerobic motile spore-formig gram-positive rod which failed to liquefy gelatin and had many, though not all, of the characteristics of the Bacillus circulans group.

Similar results were obtained with the other lots of bagasse except that organism 4 could not be isolated from lot B.

Suspensions were prepared by washing the agar slants with saline solution. They were standardized bacteriologically to contain approximately 10,000 organisms per cubic millimeter. The elements of the Aspergillus and Actinomyces cultures were similarly counted by attempting, as far as possible, to estimate the number of particles—mycelia or spores—present. It was planned to inject 5 cc. of one or another of the suspension intravenously into each rabbit twice. Suspensions of 1, 3, 4 and 5 were well tolerated. Rabbits, however, which had received a single injection (5 cc.) of suspension 2 (aspergillus) invariably died or were so sick two to three days after the first injection that it was preferred to put them to death.

The lungs, hearts, livers and kidneys of these rabbits showed numerous lesions of a necrotizing character. Mycelia were sometimes histologically demonstrable, and A. fumigatus was recovered from a blood culture at autopsy.

Sections representing the rabbits inoculated with the other micro-organisms and killed at similar intervals revealed that organisms 1 and 3 produced only minimal foreign body reaction in the lung. The cellular reaction of the lungs of the animals inoculated with organisms 4 and 5 was also slight, but abscess formation was observed in the liver in both instances. Numerous multinucleated giant cells were noted within the granulation tissue. Structures phagocytosed in their cytoplasm suggested that the giant cells were macrophages which had ingested some of the micro-organisms.

Three rabbits that were given suspensions of bagasse E in amounts and over periods similar to those employed in the first two groups withstood the treatment well. Two of them, on histologic study, showed minimal pulmonary lesions, one of them also a renal abscess, while the lungs of the third animal showed numerous foci of mononuclear exudate and of giant cell formation; polymorphonuclear leukocytes were rare, and necrosis was absent.

*Intratracheal Administration.*—The fact that bagasse injected intravenously produced severe lesions did not necessarily imply that it would call forth a similar reaction when introduced by way of the respiratory tract. A group of rabbits received, therefore, bagasse suspensions by intratracheal insufflation. For this the animals were under combined local and light ether anesthesia.

Each rabbit was given 10 cc. of suspension, an amount of fluid that is absorbed from the lungs within seventy-two hours.[6] For control purposes aliquots of the

6. Courtice, F. C., and Phipps, P. J.: J. Physiol. **105**:186, 1946.

suspensions were either autoclaved or formaldehydized by addition of 10 per cent (volume) of a 40 per cent solution of formaldehyde. After three to four days the formaldehyde solution was removed by centrifuging the particles and resuspending them in saline solution. These suspensions were sterile on culture. The animals were killed after ten days. Microscopic sections of the lungs of rabbits treated with the suspension of fresh bagasse showed numerous large pneumonic foci (fig 4). The exudate was composed of polymorphonuclear leukocytes, monocytes and multinucleated giant cells, with frequent disintegration of the exudate cells. The giant cells were of the foreign body type and contained variously shaped cytoplasmic defects which under polarized light sometimes corresponded to doublerefractile, apparently unstained foreign bodies. The interstitium was infiltrated by round cells. There was fibroblastic proliferation at the periphery of the lesion. Some bronchial lumens contained desquamated epithelial and disintegrated exudate cells. An occasional vessel was occluded by granulation tissue and its wall infiltrated by small round cells (fig. 5). One liver revealed numerous small foci of necrosis and infiltrating polymorphonuclear leukocytes.

In sections of the lungs of the control animals, lesions were infrequent, small and of granulomatous character. Giant cells were fairly numerous, but polymorphonuclear leukocytes were encountered only occasionally, and cellular disintegration was absent (fig. 6). Fibroblastic proliferation was more intense than in the first group. The vessels were free of lesions.

Suspensions of bagasse E were administered to 2 rabbits. After ten days their lungs contained fairly frequent foci of pneumonic exudate, with monocytes being prevalent in the larger and polymorphonuclear leukocytes in the smaller lesions. Multinucleated giant cells were also present. Cellular disintegration and interstitial infiltration were, however, less prominent than in the group which had received bagasse A.

Guinea pigs were subjected to similar procedures, with suspension of bagasse E, except that the amount insufflated was 3 cc. Sections of the lungs of 2 animals obtained at a ten day interval revealed several foci of a polymorphonuclear and monocytic alveolar exudate. Several alveoli in these groups contained multinucleated giant cells, one to each. Sporelike foreign bodies were seen in the cytoplasm of these cells. There was no necrosis, and no changes were found in the other organs.

*Intracutaneous Tests.*—It has been stated earlier that intracutaneous tests carried out with extracts of bagasse by two groups of authors yielded different results. This problem was therefore also investigated. Rabbits which had received two intravenous injections each of 5 cc. of bagasse suspension over a period of six days were tested by intracutaneous injection of 0.05 cc. of Seitz filtrates prepared from saline suspensions of cultures of each of the five micro-organisms mentioned earlier. The tests were made thirteen days after the first injection of the bagasse suspension.

With filtrates 1 and 4 there was a reddening of the skin within a few hours after the injection, and the reaction increased in intensity until about twenty-four hours later. A slight reaction was observed in one instance with filtrate 2. The other filtrates and saline solution, which was used as control, gave negative results. A normal rabbit, however, tested with identical preparations showed similar results.

That sensitization is not an essential factor in the genesis of the experimental disease was also indicated by the fact that a single injection of a more concentrated suspension of bagasse A produced lesions similar to those due to repeated injections.

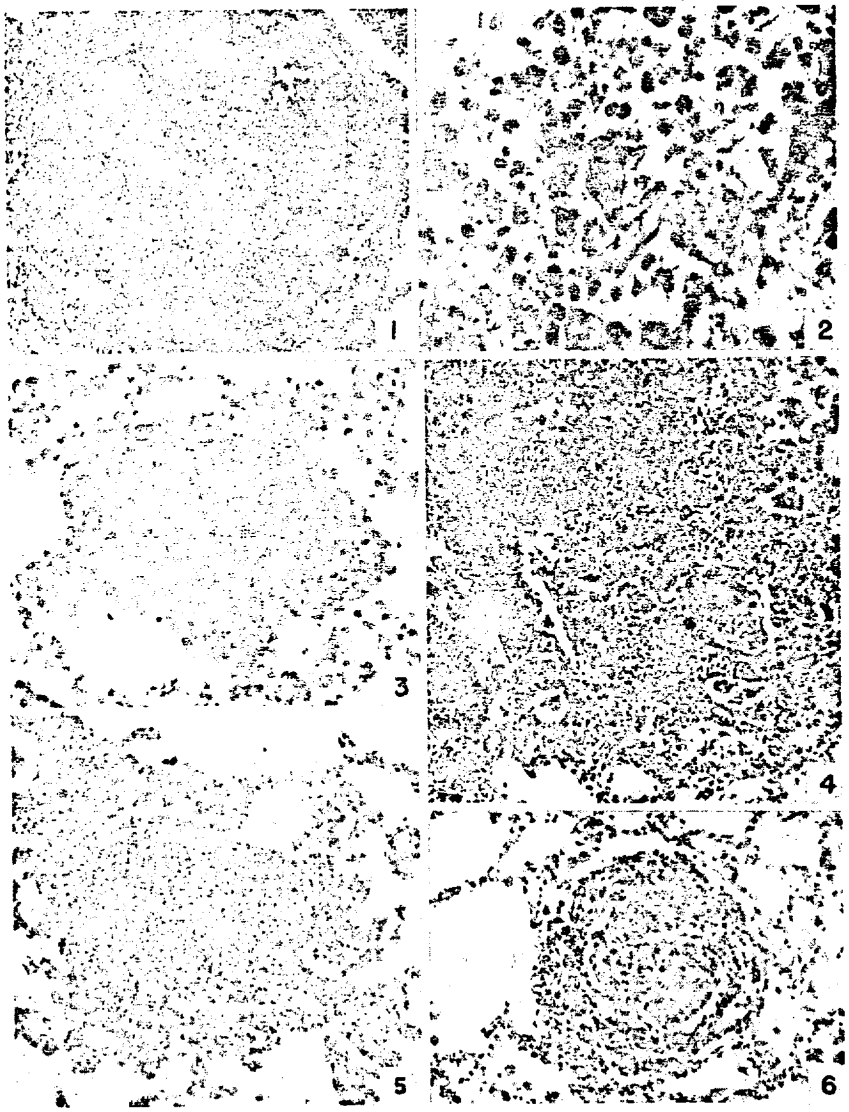


Fig. 1.—Rabbit given intravenous injections of a suspension of unheated bagasse A; third day; lung; focus of necrotizing pneumonia; Masson stain; × 75.

Fig. 2.—Rabbit given intravenous injections of a suspension of unheated bagasse A; third day; kidney; mycelial fragment and spore; Masson stain; × 476.

Fig. 3.—Rabbit given intravenous injections of a suspension of autoclaved bagasse A; third day; lung; granulomatous lesion; hematoxylin and eosin; × 238.

Fig. 4.—Rabbit given intratracheal insufflation of fresh bagasse; tenth day; lung; pneumonic exudate of polymorphonuclear leukocytes, monocytes and foreign body giant cells; hematoxylin and eosin; × 136.

Fig. 5.—Rabbit given intratracheal insufflation of fresh bagasse; tenth day; lung; vessel occluded by granulation tissue: hematoxylin and eosin × 156.5.

Fig. 6.—Rabbit given intratracheal insufflation of autoclaved bagasse; tenth day; lung; foreign body granuloma; hematoxylin and eosin; × 177.

## COMMENT

In the cases reported so far human bagasse disease occurred after an exposure of several weeks or months. The pathologic changes described here resulted from short term experiments and should not be taken, therefore, as a basis for comparing the lesions morphologically.

Suspensions of unheated bagasse given intravenously proved fatal to rabbits except when given in small doses. The fact that numerous necrotizing lesions with fragments of fungi demonstrable within them were found in the kidney and the liver while the highly refractory bagasse fibers were not seen there, together with the fact that there were no lesions in these organs in animals given injections of autoclaved bagasse, suggests that the fiber itself does not contribute to the causation of the experimental disease. It may be assumed, however, that the process of autoclaving changed the structure of the fiber, rendering it less harmful. Thus, resort was taken to formaldehydizing, a procedure that would affect the micro-organisms of the suspension and change only amino groups of protein particles possibly present in the bagasse fibers. The pathogenicity of bagasse, however, was equally abolished by the second procedure.

Among the micro-organisms isolated from bagasse, the aspergilli proved to be the most harmful for rabbits. These are ubiquitous fungi and are known not only for their toxic effect when injected intravenously into animals but also for their occasional pathogenicity for man. In view of the cosmopolitan distribution of A. fumigatus in the soil and in vegetable matter, it is difficult to attribute human bagasse disease to these organisms alone, since similar respiratory disease has not as yet been noted among many other occupational groups equally exposed to these fungi. Experiments employing prolonged exposure or providing longer intervals are necessary to decide whether aspergillosis, alone or in combination with other factors, simulates in its morphologic aspects human bagasse disease.

A slight but distinct difference was noted between the lesion produced by bagasse A and that by bagasse E, the changes produced by the latter being less severe. Bagasse disease has, however, rarely if ever occurred in men working in places where bagasse E was collected, and thus its pathogenicity for rabbits would represent a failure to supply the experimental corollary. Among the microbial contents of bagasse E, however, were also aspergilli, and it may well be that the particular susceptibility to these fungi enhanced the severity of the lesions in rabbits. The less serious character of the lesions occurring in guinea pigs would support this assumption.



## SUMMARY

Final interpretation of the results of these experiments has to be postponed until more information concerning the pathogenicity of the micro-organisms and of the fibers described will be available. Preliminarily it may be said, however, that the bagasse fiber itself under the test conditions described is a rather inert material, that the acute inflammatory process caused by bagasse is due to micro-organisms, probably fungi, attached to the bagasse, and that the lesions in no instance resembled those in human or experimental silicosis.

# The Pathogenicity of Bagasse, II. Effect on Rabbits of Prolonged Exposure to Bagasse.*

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The clinical and industrial health problems of Bagasse Disease have attracted increasing attention.[1-12] In spite of careful observation and biopsies on patients suffering of this disease, its pathogenesis remains obscure.[2]

* Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the author.

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Various factors have been suggested as etiologic agents: the particular composition of the fiber itself, fungi and micro-organisms attached to the fiber, and the high silica content. Allergic phenomena also entertained as a possible etiologic mechanism[3] seem, on the basis of experimental evidence,[4] less likely to be involved.

The problem of establishing whether the fiber itself, or the micro-organisms growing in abundance on it,[4,5] is responsible for the disease was approached experimentally by comparing the lesions produced by either untreated, autoclaved, or formalized bagasse.[4] In short term experiments a striking difference was observed. Rabbits developed a rapidly progressing, even fatal, disease after intravenous or intratracheal administration of fresh bagasse, while the autoclaved or formalized material produced only a foreign body reaction limited to the lungs. In the present report these experiments were extended in order to study the character of the lesions at longer intervals, to resolve the complex histopathology of the lesions into components that could be correlated with the various ingredients of bagasse dust, and to compare the morphology of the experimental lesions with that of the human disease.

*Material and methods.* For intratracheal insufflation, a procedure described earlier was employed.[4] The attempt to expose animals

Proc. Soc. Exptl. Biol. Med.
70(4): 697-702, 1949

TABLE I.
Rabbits Exposed to Bagasse in Dusting Chamber.

| Rabbit No. | No. of hours exposed | Duration of exposure, days | Day after last exposure that animal died (d) or was sacrificed (s) |
|---|---|---|---|
| 296 | 270 | 108 | 11th (s) |
| 297 | 270 | 108 | 21st (s) |
| 347 | 30 | 6 | 1st (d) |
| 356 | 72 | 15 | 1st (d) |
| 359 | 90 | 15 | 1st (d) |
| 362 | 180 | 44 | 24th (s) |
| 352 | 30 | 6 | 30th (s) |
| 363 | 180 | 44 | 36th (s) |
| 348 | 54 | 12 | 36th (s) |

to a continuous and somewhat controlled flow of dust for days or weeks met with difficulty. An arrangement, similar to that recommended by Sonkin *et al.*[6] proved unsuccessful because of the hygroscopic bagasse powder rapidly becoming sticky and plugging the jet. Shaking a large amount of bagasse and maintaining the dust in the air by means of a fan or blower resulted in unequal distribution in the dusting chamber. Finally, resort was taken to a modification of the relatively simple method employed by Gardner.[7] Bagasse was finely shredded in a Waring blender and strained through a wire gauze sieve, 150 meshes per inch. Dusting was carried out for various periods during the day time. (See Table I). Approximately 15 g of bagasse were expended during 6 hours of dusting. The animals with their fur thickly coated with dust were then replaced in their cages.

To secure ash, bagasse was kept in an electric furnace at 850°F, with air blown into the oven to insure oxygenation. The resulting ash was ground in a glass homogenizer. The average yield was 5.74%. Hunter and Perry[5] as well as Koven,[12] reported 3 to 4%. The silica content of the ash was 43.34 and 43.05%.‡ The ash of 10 g bagasse, ground with the addition of saline, was made up to 90 cc. Each cubic millimeter contained approximately 35,000 particles. Its total content of solid particles, estimated volumetrically after centrifugation, was twice that of suspension of bagasse.[4] The mineral content, however, was about 10 times that of the suspension of bagasse fiber.

An extract of the resinous substances was obtained by refluxing 5 g of shredded bagasse with 100 cc of petrol ether or benzol for 10 hours. The solvent was evaporated from the filtrate. The residue suspended well in 15 to 20 cc of water, to which 2 drops of monoethanolamine had been added.

*Results. A. Intratracheal insufflation of bagasse.* Rabbits studied at 20 and 35 days after the intratracheal insufflation of 10 ml of suspension of fresh bagasse showed frequent and large pneumonic lesions, with the alveolar exudate predominantly monocytic in character, though polymorphonuclears were numerous in places. The interstitium was infiltrated by small and large round cells. Fibroblastic proliferation was noted at the periphery of several lesions. Other lesions were of a foreign body granulomatous type and composed of multinucleated giant cells and mononuclears grouped together by bundles of fibroblasts. Cytoplasmic defects of irregular shape were often seen in the giant and mononuclear cells, but birefringent bodies could be identified under polarized light only in a few instances. From the pulmonary lesions of one of the rabbits (35th day) an Aspergillus was isolated on culture. In some sections radiate bodies (Moore[8]) could also be identified. Rabbits treated similarly with autoclaved or formalized bagasse and studied at identical intervals revealed lesions composed of one to several multinucleated giant and mononuclear cells, both showing cytoplasmic vacuoles. Slight fibroblastic pro-

‡ These values were obtained on a single sample and carried out by Dr. Carl Tiedeke, New York City.

liferation and a few small round cells were seen at the periphery of some of the lesions, rendering them granuloma-like. There was little difference between the morphology of these lesions and those observed at 10-day intervals.[4]

*B. Effect of ash and resins of bagasse.* For the purpose of differentiating the effect of minerals present in bagasse from that of the fiber as a whole, 2 rabbits received each 10 ml of ash suspension, as described under Materials and Methods, by the intratracheal route, and were sacrificed 35 days later. Microscopic sections revealed occasional foreign body giant cells, both single or in small groups, in the interstitial pulmonary tissue. Some irregular shaped cytoplasmic defects in these cells corresponded, under polarized light, to double refractile bodies. In the pulmonary sections of one of the animals two small granulomatous lesions, composed of a few multinucleated giant cells and fibroblastic proliferation were noted; and in a section of the other animal a few alveoli plugged by young connective tissue were noted. (Fig. 1).

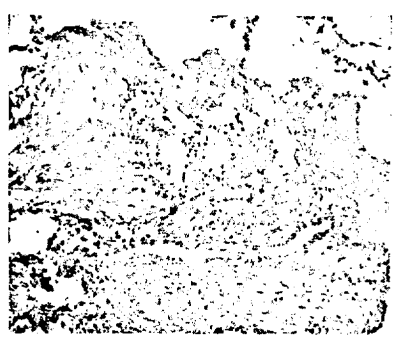

FIG. 1.
Rabbit 328. Treated intratracheally with ash of bagasse; 35th day. Lung. Masson strain. ×75.

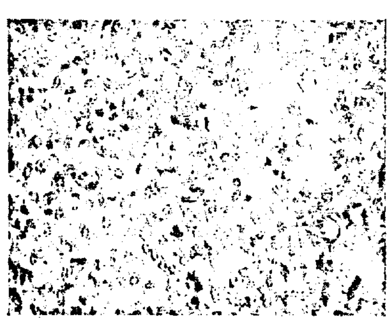

FIG. 2.
Guinea pig. Intraperitoneal injection of ash of bagasse; 90th day. Peritoneal tissue. H. & E. stain. ×165.

Intravenous administration of similar material in repeated small doses, totaling 8 ml produced occlusion of numerous capillaries by multinucleated giant cells which had formed around irregular shaped, sometimes highly refractile, foreign bodies. Similar giant cells were also found occluding lymphatics. This type of lesion was observed at 3 and 4 day intervals as well as at 20 and 35 days. In the latter group they differed only by being less numerous and by the occasional presence of a few small round cells or slight fibroblastic proliferation around the giant cells. The pulmonary changes in two rabbits, treated similarly and sacrificed at 55 days, were almost identical to those of the aforementioned ones. It is noteworthy that the other organs of these animals were free of lesions.

Three guinea pigs each received intraperitoneal injections of 2 cc of the ash suspension, and were sacrificed 90 days later. Two of them revealed granulomatous lesions attached to the visceral and parietal peritoneum, and composed of numerous large giant cells, mononuclears, and slight fibrous tissue proliferation (Fig. 2). Numerous variously shaped foreign bodies were within cytoplasmic vacuoles of these cells. None of these lesions resembled those seen in experimental silicosis.

The extent and number of lesions, as well as the intensity of the cellular reaction in the rabbits that received ash suspension were strikingly less than in the animals treated with autoclaved or formalized bagasse, although the mineral content of the material administered was a multiple of that in the former group.

Browne,[9] in an early investigation of the composition of bagasse, pointed to its high resin content. Resins are not innocuous substances, although the literature on this subject is scanty (Hirsch and Russel[10]). An attempt was, therefore, made to arrive at an appraisal of the biologic properties of the resins present in bagasse. Extracts, prepared as stated under Methods, and suspended in ethanolamine water were administered intratracheally so that each of three rabbits received the total from 2.5 g of bagasse. The animals were sacrificed on the 35th day. A moderate number of multinucleated giant cells of the foreign body type were seen in the interstitial tissue of the lungs. Some of them contained large, irregularly shaped, foreign bodies which did not rotate the beam of polarized light. There was no other cellular reaction.

*C. Exposure to bagasse dust.* Animals were exposed to dust for periods indicated in Table I. For dusting rabbits 296 and 297, various mechanisms including the jet devised by Sonkin *et al.*[6] were employed. Only for the last 10 hours of exposure were these animals kept in the dusting chamber used for all other animals listed in Table I. Between the two animals there was a striking difference in type and extent of lesions. A few alveoli containing a mononuclear exudate were the only changes seen in rabbit 297. Although rabbit 296 was sacrificed 10 days later, its necropsy revealed extensive acute inflammatory changes. In the lung, numerous alveoli were filled by a polymorphonuclear and monocytic exudate with some of their nuclei showing pyknosis and karyorrhexis. Disintegrated cells were also noted in the perivascular lymphatic tissue. Foci of necrosis were present in liver and spleen.

Three animals, kept in the dusting chamber as indicated (Table I), died after 30, 72 and 90 hours of exposure. (Rabbits 347, 356 and 359). It is noteworthy that their exposure mates survived for a prolonged period. The microscopic preparations of the first rabbit revealed a hemorrhagic pneumonia; those of rabbit 359 revealed fairly numerous mononuclear cells in alveoli and in distended lymphatics. Small foreign bodies were seen in many exudate cells. Two healing myocardial infarcts may have accounted for the early death of this animal. The sections of rabbit 356 revealed an extensive pneumonic process with the exudate being polymorphonuclear in places, in others predominantly mononuclear. Many bronchioli were plugged by a similar, sometimes disintegrated, exudate. Occasional organization of the bronchiolar and bronchial exudate was found (Fig. 3). Multinucleated giant cells were infrequent. In addition to numerous small variously shaped foreign bodies there was noted an occasional club-shaped body, continuous with a fragment of a mycelial-like structure (Fig. 4). Frequently groups of large mononuclears with a foamy cytoplasm were seen both in alveoli and interstitium. Similar changes were also responsible for some polyp-like protrusions of the interstitium into the alveolar lumina. Some of the alveoli were lined by a cuboidal metaplastic epithelium.

Four animals were exposed to bagasse dust from 30 to 180 hours, and sacrificed at intervals from 24 to 36 days after the last exposure. These animals, because of the approximating interval, as well as the similarity

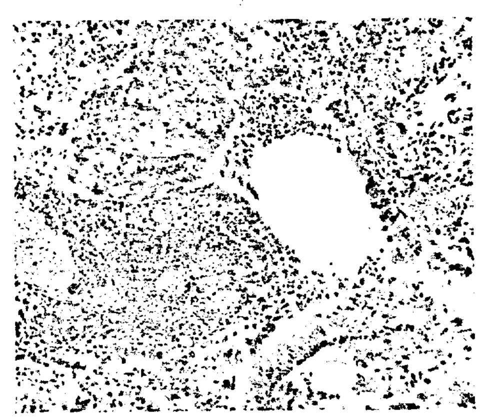

FIG. 3.
Rabbit 346. Exposed to bagasse dust for 72 hours. Died. Lung. H. & E. stain. ×100. Bronchioli plugged by exudate. Interstitial infiltration by inflammatory cells.

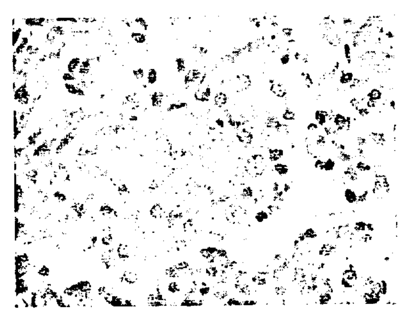

FIG. 4.
Rabbit 356. Lung. Masson stain. ×425. Spore and mycelia-like structure; foreign body giant cell.

of lesions, may be considered together. There were many alveoli in groups of 3-20 which were filled by closely packed large round or polygonal cells, some of which could be identified as mononuclear phagocytes. Their cytoplasm contained brown dust-like material and also birefringent rods. A few multinucleated giant cells of the foreign body type and occasional polymorphonuclears were present. There was no necrosis. In pulmonary sections of rabbit 363 there was a marked thickening of the interstitium by monocytic infiltration and fibroblastic proliferation sometimes forming protrusions (Fig. 5) similar to those observed in rabbit 356.

Three guinea pigs (337, 338 and 339) were also exposed in the dusting chamber for a total of 77 hours over a period of 18 days, and sacrificed 10 days later. The short interval was selected in order to observe any acute inflammatory changes which might have subsided at a later date. In the pulmonary sections some alveoli and bronchioli contained an exudate of large vacuolated mononuclear cells and an occasional polymorphonuclear. Elsewhere, large multinucleated giant cells were seen. Numerous foreign bodies were present within cells of both types. When compared with the lesions of rabbits exposed for a similar length of time, the almost complete absence of an acute inflammatory response in the guinea pig was striking.

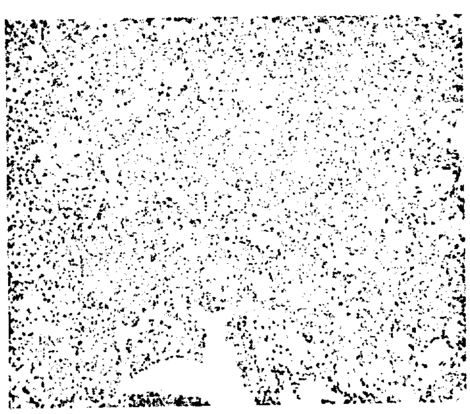

FIG. 5.
Rabbit 363. Dusted 180 hours, 36th day. Lung. H. & E. stain. ×60. Marked interstitial infiltration.

*Discussion.* The striking difference between lesions resulting from the administration of live bagasse, and those from bagasse dust with all living matter killed by either autoclaving or formalizing, as described first in short time experiments, was also manifest in animals kept alive for longer intervals. This is suggestive evidence that some living matter attached to the bagasse fiber, in itself an injurious agent, enhances the effect, and produces an additional pathologic change. The bagasse fiber, without living matter, elicits a long-standing foreign body reaction. Bagasse dust in the native state, when inhaled or insufflated, calls forth, in addition to the foreign body granuloma, an acute inflammatory response which, in view of its presence many days after the exposure, allows no other interpretation than that self-propagating micro-organisms act upon the tissue of the host. For the rabbit, an aspergillus seems to be the pathogenic agent. It could be recovered from the pulmonary lesions 35 days after intratracheal administration of bagasse dust. This finding would support the theses of other authors[3,5,12] that fungi play an important part in the pathogenesis of the human disease.

Two components of the bagasse fiber could be demonstrated as being responsible for a long persistent tissue reaction, although the latter is of minor degree. One of them, the mineral particles, is of interest for the high silica content. But none of the lesions produced by the mineral ash resembled those of human or experimental silicosis. This would bear out the assumption of several authors that human Bagassosis is not caused by the high silica content of the bagasse fiber. The resins similarly contribute to the persistence of the lesions, as evidenced by the presence of giant cells 35 days after intratracheal insufflation. It also could be established that the resins, at least in their extracted form, do not contribute to the birefringence of the bagasse particles.

The most interesting part of the investigation was the effect of bagasse dust when inhaled by animals under conditions simulating those under which the human disease is acquired. It was soon apparent that some of the animals reacted violently to the dust with instant and protracted cough, and developed a rapidly progressing pneumonia. The complex morphology of the lesions found in these animals includes hemorrhagic pneumonia, bronchiolitis, with plugging of passageways by cellular exudate and debris, interstitial thickening by exudate and fibroblastic proliferation, as well as of foreign body reaction. On the other side are the animals that offered a higher resistance, possibly aided by elimination of some particles by the upper respiratory channels. These animals probably would have survived indefinitely and demonstrated the ability to resolve gradually the lesions which they undoubtedly harbored at an earlier date.

Although these two groups of animals represent an interesting parallel to the selective morbidity among workers in the bagasse industry, a comparison of the morphology of the human with that of the experimental disease is hindered by the scarcity of human material available.§

Of the 2 cases that came to autopsy (Sodeman,[11] Hunter and Perry[5]) only one has been reported so far. Large spicules, as illustrated in Sodeman's case, could not be found in the tissue of animals that were exposed to the dust. Apparently particles of that size could not pass the smaller respiratory lumina of the animals. Other characteristic features are interstitial fibrosis, bronchiolitis,[5] and the presence of numerous large foamy alveolar cells filling the alveolar spaces.[11]

In the experimental lesions interstitial fibrosis was scanty. This may be due to a greater resolving power of the animal tissue or to the fact that the more susceptible animals succumbed too early (6 and 15 days) to have developed extensive fibrosis. Fibroblastic proliferation, however, was observed. Large foamy exudate cells and plugging of the bronchi were the features whereby the experimental most closely resembled the spontaneous disease.

The character of the lesions in the guinea pig differed strikingly from that in the rabbit. These represented a response to foreign bodies and lacked the acute inflammatory and progressive component, and are apparently due to the fact that the guinea pig is not susceptible to the organisms associated with bagasse.[4,5]

*Conclusions.* These experimental and comparative studies permit the conclusion that the inorganic part of the inhaled bagasse dust produces a long-standing tissue reaction which is primarily a foreign body response. It is unlike silicosis and amenable to healing by resolution. Superimposed on these lesions there occurs in those animals which are more susceptible to the causative microorganisms acute bronchiolitic and pneumonic changes which, if sufficiently extensive, may cause death of the animal. A similar combination of etiologic factors seems to be the most plausible explanation of the complex picture of human bagasse disease.

*Summary.* Bagasse irrespective of the route of administration, produces a complex and frequently progressive inflammatory reaction of the exposed animal. By employing native, in contrast to autoclaved bagasse and its extracted resins and minerals, it could be demonstrated that the fiber itself calls forth a long-standing foreign body reaction which is amenable to healing. The progressive inflammatory reaction and death of the animal, however, are due to microorganisms attached to the bagasse. In the instance of the rabbit, aspergilli are the pathogenic agents. The points of similarity of the experimental lesions to those observed in humans are discussed. None of the lesions resembled silicosis.

I wish to express sincere thanks to the Hospital Photographic Laboratory, Letterman General Hospital, San Francisco, for preparing these microphotographs.

§ Dr. W. A. Sodeman kindly made available several slides of the pulmonary lesions of the case observed at Tulane University.

# BRONCHIOLITIS RESULTING FROM THE HANDLING OF BAGASSE

BY

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Bagasse is sugar cane after the sugar has been extracted. Because of the toughness of its fibres and their good insulating properties it is used for making boards for interior decorating and for thermal insulating purposes. The sugar cane which is used for this purpose is grown in Louisiana and shipped to to this country in bales. When the bales are packed in America the bagasse contains 4 per cent. of glucose, but on arrival in England it is sugar free.

Until the outbreak of war the bales were broken by a wet process: they were placed under water in a soak pit, broken, and then carried by a conveyor belt from the small house in which this process was carried out to the main factory for processing. At the end of 1939, in order to save shipping space, the bales were packed more firmly and it proved no longer possible to break them in this wet process. A machine, known as a shredder, was therefore introduced to break the bales. This consisted of a wheel with multiple blades which revolved inside a case. The bales were first broken with a pick-axe and the sections then thrown into the case. The bagasse was thus shredded by this dry process and the small pieces were carried by the conveyor belt as before. This process proved to be very dusty. Bagasse, as found at the factory, consists mostly of cellulose fibre, though some of the cellulose is present in crystalline form. It also contains 1 per cent. of protein. Nagelschmidt found that bagasse gave 3 per cent. of ash on ashing at 400° C. By alternating treatment of this ash with cold dilute acid and hot dilute alkalies, over 80 per cent. could be dissolved. This dissolved portion contained the amorphous silica which came to about 50 per cent. of the total ash. The residue contained much quartz. Microscopic and x-ray diffraction analysis put the quartz at about 3–5 per cent. of the total ash. This amorphous silica formed roughly 1–2 per cent. of the bagasse and quartz 0·1–0·2 per cent.; many of the quartz particles were 20–30$\mu$ in size. It was most improbable, therefore, that any risk of silicosis could arise in handling bagasse. Bagasse was also found to contain many fungi. J. T. Duncan examined samples and also dust from the shredder room. He found many fungi present, and estimated that one gramme of the airborne dust contained 240 million fungal spores. These consisted of the uncultivable teleospores of fungi of the order Puccinales (Rusts), as well as the conidia of many species of saprophytic fungi. About 20 different species were isolated in culture, including *Paecilomyces varioti, Aspergillus fumigatus, A. niger, A. terreus* and *A. candida, Trichoderma lignorum, Monilia sitophilia, Aleurisma sp.* and species of Penicillium, Mucor, Rhizopus, etc.

In 1940, after the installation of the dry bale breaking machinery, cases of respiratory illness began to appear among employees working the shredding machine and breaking the bales. These cases were observed by Lloyd (1940) at the Brompton Hospital. He considered that he was dealing with an unusual kind of pneumonia which was related to bagasse, but did not think that there was sufficient evidence to establish the aetiology. He consulted E. L. Middleton, H.M. Medical Inspector of Factories who advised that the machinery should be modified by a jet of water being directed on to the wheel to allay the dust. This advice was carried out in 1941, and until 1944 no further case of respiratory disease which could be attributed to the bagasse occurred in England.

## Review of Literature

Jamison and Hopkins (1941) described the case of a young negro labourer who was employed in 1940 unloading bagasse from a ship at a board-making factory in New Orleans. This was a very dusty occupation. He developed an acute febrile illness with marked dyspnoea, cough and scanty blood-stained sputum. Physical signs showed râles scattered throughout both lungs. X-rays showed 'miliary mottling' through both lung fields, but these cleared in the course of 2 months, leaving a normal healthy picture. The patient recovered completely. From a concentrate of a 24-hour specimen of his sputum a fungus was grown on two occasions. The authors, however, while stating that in their opinion this was the cause of the illness, fail to state the nature of the fungus.

Castleden and Hamilton-Paterson (1942) reported four case of 'bagassosis,' an industrial lung disease. The first was a boy of 19, who after working for six weeks in the spring of 1941, developed a bilateral pneumonia which radiologically showed an extensive consolidation in both lungs with enlarged mediastinal glands. The appearances did not show the typical miliary mottling of the syndrome associated with bagasse, but the process may have become confluent in this particular case, though it is impossible to distinguish from the atypical pneumonia which was prevalent in that year, and which has been well described by Drew, Samuel and Ball (1943), among others. Case 2 was an electrical mechanic aged 37, who was not himself engaged on



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the work of breaking the bales. The machinery, however, was new and there were frequent breakdowns. He therefore spent considerable time in the house effecting repairs. X-ray of his chest in 194[illegible] showed no abnormality beyond a catarrhal bronchitis. However, since that time he has developed extensive progressive fibrosis of both lungs. He subsequently died in 1944 and an account of the necropsy is given later in this paper. (Case 12.) Case 3 showed no radiological changes in the lungs, and Case 4 was a man aged 44 who had previously worked for 17 years in the Durham coalfield and showed the x-ray appearances which have been termed reticulation by Hart and Aslett (1942). Castleden and Hamilton-Paterson also described skin tests which they had carried out on some of the workers. These showed that some developed a skin sensitivity to extracts of bagasse. Sodeman and Pullen (1944) repeated these tests in persons exposed to bagasse, and in a group who had not been exposed. They failed to find a negative reactor in either group. Castleden and Hamilton-Paterson therefore left the disease in a very obscure position, especially as the third and fourth cases show no disease that can be clearly attributed to bagasse and the fourth man had a pneumonokoniosis caused by his work as a collier.

A further case was reported from New Orleans in 1944 by Jamison, Bryan and Day in a negro man aged 32, who had been loading railway freight cars for a month. He developed dyspnoea and x-ray of his chest revealed infiltration with a miliary appearance which cleared completely in the course of four months. No fungi were found in this case.

Finally, Sodeman and Pullen (1943) gave an account of a fatal case and (1944) an account of 11 further cases. They say that shortness of breath was invariably the chief complaint, but that cough was an early and important symptom. In four instances haemoptysis occurred: it was variable in amount, but lasted only a few days. The sputum was scanty and mucoid. Intermittent fever with temperature rising to 102 F. was observed and persisted up to three or four weeks. X-ray examination of the chest showed a miliary mottling throughout both lungs, most dense in the hilar areas in all cases. White cell counts were over 10,000 in 10 instances with a polymorphonuclear leucocytosis. Needle biopsy specimens were obtained from the lung of one patient in the sixth week of the disease,

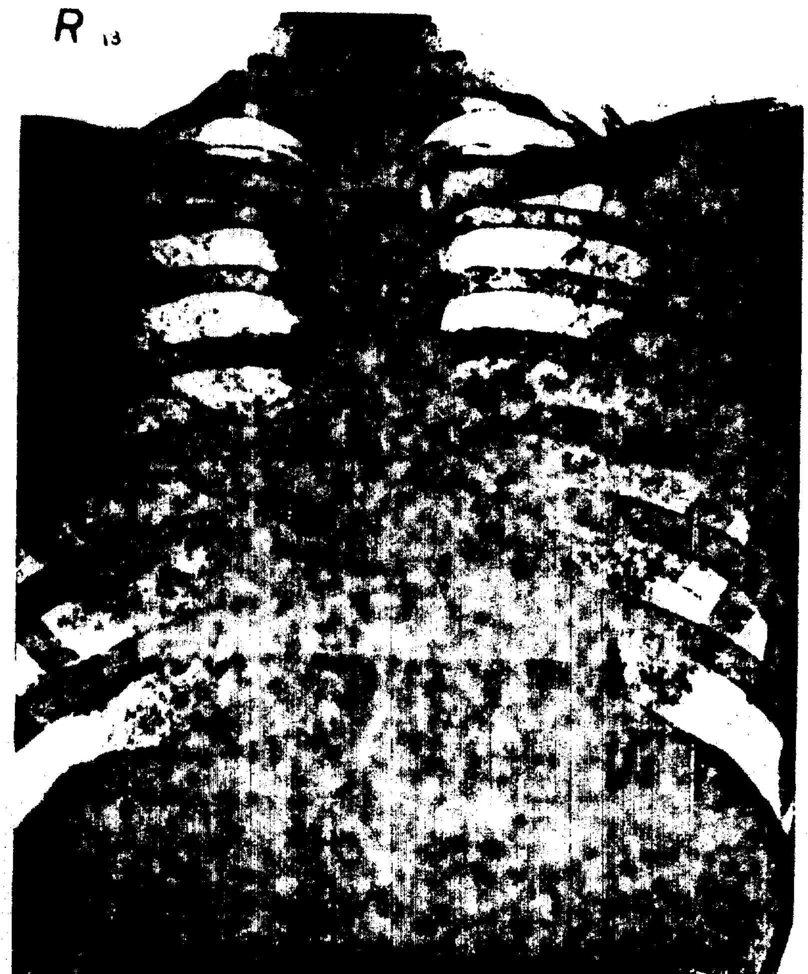


FIG. 1. Case 1 in acute stage showing diffuse mottling with scattered confluent areas.

and sections were taken at necropsy from the lung of the patient who died. These showed pulmonary tissue with several 'spicules' of an irregular foreign material embedded in it. There was a fibroblastic reaction of the interstitial tissue of the lung. There were many large cells with a foamy cytoplasm in the alveolar spaces. The foreign bodies were microscopically similar to bagasse, and under the polarizing microscope these 'spicules' were seen to rotate the plane of polarized light; many smaller scattered pieces with an average diameter of 2·8μ were also seen.

### Present Investigation

An attempt has been made to ascertain what has happened to all the men who worked on the bagasse shredder at the factory in England. It was discovered that in 1940 14 men were employed on this machine for continuous periods of more than 3 days; in 1941 20 men, and in 1942 10 men. These men worked in pairs for two weeks by day, followed by a two weeks' night shift. The work was considerably more dusty at night since blackout regulations necessitated the closing of the large doors to the shed which housed the machine. Of the 14 men employed in 1940, 13 were traced; of the 20 in 1941, 18 were traced; and of the 10 in 1942, 8 were traced. As the machine was in an experimental stage in 1940 the assistant works manager, the chemist, the personnel manager, an electrical mechanic and a carpenter also spent a considerable amount of time in the shed. All five of these have been traced and examined. Of 13 men traced who worked on the shredder in 1940 7 showed a characteristic acute respiratory illness, similar to that already described by Lloyd at the Brompton Hospital and the American workers; and of the 8 men employed during the first three months of 1941 3 showed signs of this illness.

Thus, out of 21 men employed on the shredder in a period of 15 months, 10 (47·5 per cent.) developed the illness. The onset of symptoms usually occurred after the men had been working on the machine for 8 weeks. The disease manifested itself as an acute febrile illness with extreme shortness of breath, cough with scanty black, stringy sputum and occasional haemoptysis. Signs were scattered throughout both lungs, and x-rays of the chest showed miliary shadows throughout both lung fields. The appearances

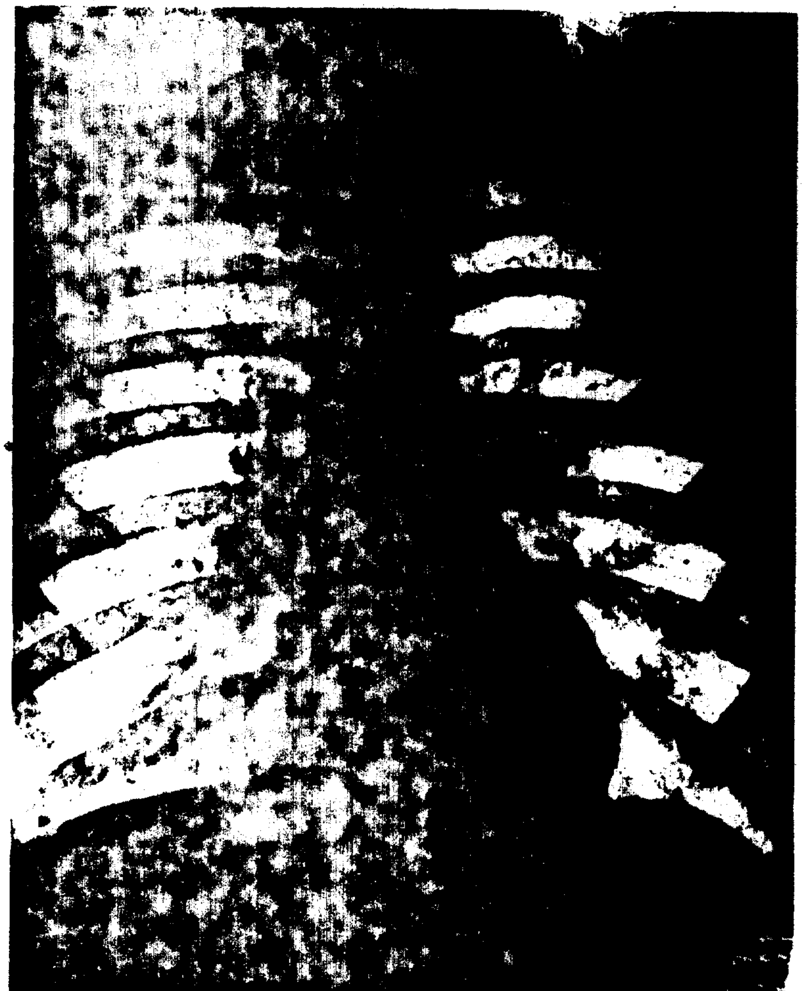

FIG. 2. Case 1, three years after the acute illness.

FIG. 3.—Case 4 in acute stage showing extensive mottling with confluent areas.

were therefore those of an acute bronchiolitis. The patient's symptoms gradually improved over a period of six weeks, at the end of which time he had recovered and skiagrams showed the lung fields to be quite clear. One patient in 1941 died after [illegible]5 days' illness, but unfortunately no necropsy was performed. Except for the electrical mechanic, the other men of the technical staff showed no evidence of disease in their lungs at this time. The electrical mechanic (case 2 Castleden and Hamilton-Paterson, case 12 this paper) had repeated acute respiratory illnesses which progressed to a chronic condition. He finally died in 1944, and necropsy revealed chronic bronchiolitis and bronchiectasis. These cases give strong evidence that a specific disease manifesting itself by acute bronchiolitis, collapse, and pneumonia has occurred in the lungs of men who handle bagasse. The case histories of the ten men described above who showed specific disease follow.

**Case 1.** G. J., aged 28. He had worked for one year in the South Wales coalfield, three years in a rubber factory, and six years in the regular Army before joining the firm handling the bagasse in June 1938 as a labourer. He worked on the shredding machine from December 1st, 1939, to January 29th, 1940, when he was taken ill. He was admitted to the Brompton Hospital on March 16th, 1940, under Dr. W. E. Lloyd, complaining of shortness of breath, cough with purulent sputum, which was streaked with blood on one occasion, sweating and loss of weight. On examination he had a fever to 101 F., which persisted for three weeks. There were impaired percussion note and many coarse râles scattered throughout both lungs. X-ray of his chest showed a diffuse mottling with some confluent areas scattered throughout both lungs. There was considerable hilar enlargement (fig. 1). Further x-rays taken on April 15th, May 6th and July 20th showed that the process rapidly cleared. On July 15th, 1943, he was well, but still suffered from some shortness of breath and cough. He had no abnormal physical signs and x-ray of his chest revealed no abnormality (fig. 2).

**Case 2.** W. D., aged 65. He had worked as a newspaper roundsman, a dock labourer, in the Merchant Navy, in the Army, and as a builder's labourer before joining the firm in September 1937. He worked as a labourer until December 1939, but in that month and January 1940, when he was taken ill, he worked on the shredding machine. He was admitted to the Central Middlesex Hospital under Dr. H. Joules on April 25th, 1940, complaining of shortness of breath, cough with a

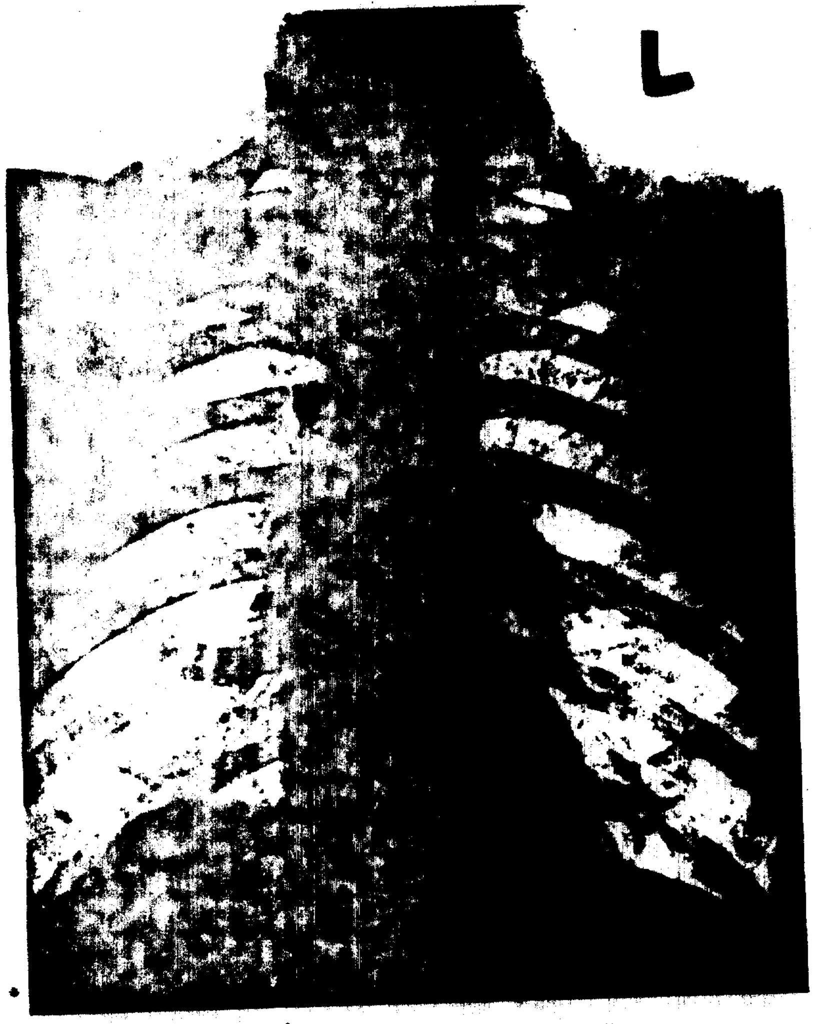


FIG. 4.—Case 4: three years after the acute illness.

considerable amount of sticky sputum, and progressive loss of weight. On examination his apex beat was not displaced, his pulse rate 88, blood pressure 150/105. There was slight thickening of the peripheral arteries and his aortic second sound was accentuated. He was cyanosed and dyspnoeic: the percussion note was normal and the breath sounds vesicular. Crepitant râles and occasional rhonchi were heard all over the chest. His sputum was negative for tubercle bacilli and lung fibres. The blood sedimentation rate was 40, and his blood count showed no abnormality. X-ray of his chest on April 27th, 1940, showed a diffuse miliary mottling scattered throughout both lung fields. By May 24th, 1940, this had substantially cleared, and on June 4th, 1940, he was discharged. Further x-rays taken on September 5th, 1940, and July 15th, 1943, revealed no abnormality, although he still complained of a severe winter cough with thick black sputum, and on examination there were scattered crepitations throughout both lungs.

**Case 3.** T. H., aged 29. He had worked as a pit-head worker in Scotland for 5 years, and had then been unemployed until he joined the firm on January 21st, 1940. He worked as a labourer until March 16th, 1941, and then worked on the shredding machine until he was taken ill on April 27th, 1941. He was extremely short of breath, and had a cough with black stringy sputum; no haemoptysis and no pain. He was in bed for 3 weeks with a temperature up to 103° F. for 3 days. An x-ray was taken of his chest at Wembley Hospital on May 29th, 1941, and this showed mottled opacities scattered throughout both lungs, their frequency being greater on the right side. On September 23rd, 1943, he was quite well, working at the degreasing of metal sparking plugs. He had no symptoms, no abnormal physical signs, and an x-ray showed no evidence of disease in the lungs.

**Case 4.** A. W., aged 54. He had worked as a farm labourer and in the Army until he joined the firm on July 9th, 1940. He then worked on the shredding machine until August 22nd, 1940, when he was taken ill. He was admitted to St. Charles Hospital, Ladbroke Grove, on August 28th, 1940, complaining of severe cough with purulent sputum, shortness of breath and night sweats for two weeks. On examination there were scattered râles over both bases and rhonchi at the left apex. He had clubbing of the fingers. During his first week in hospital he had a fever up to 100·5° F. Examination of his sputum showed no tubercle bacilli. X-ray of his chest on August 28th (fig. 3) showed very extensive mottling with some confluent areas throughout both lungs. X-ray examination on September 30th, 1940, showed that this process had almost cleared, and he was discharged from hospital on November 3rd, 1940. On July 15th, 1943, he was well, but still complained of some shortness of breath. On examination there were no abnormal physical signs. X-ray of his chest revealed no abnormality (fig. 4).

**Case 5.** S. B., aged 40. He had worked as a building labourer until he joined the firm on July 16th, 1940. He worked on the shredding machine from July 16th to September 1st, when he was taken ill. He was admitted to Willesden General Hospital under Dr. Pearse Williams, complaining of cough with a small amount of muco-purulent sputum, shortness of breath and sweating for 2 weeks, and slight recent loss of weight. There was no history of haemoptysis. On examination there was impaired percussion note and many râles throughout both upper zones. Sputum contained pus and showed numerous acid-fast bacilli. On culture streptococcus viridans, staphylococcus aureus and micrococcus catarrhalis were present. Dr. Rohan Williams reported on an x-ray taken on September 12th, 1940, as follows:— Bilateral diffuse parenchymal inflammatory changes in both mid and lower zones, the upper zones being relatively clear. Probably a diffuse bronchogenic tuberculosis. Dr. Rohan Williams suggested the possibility of an occupational cause for the appearances. The patient was seen by the Tuberculosis Officer who agreed that he was suffering from pulmonary tuberculosis, and he was admitted to Clare Hall Sanatorium in November 1940. His symptoms had disappeared by then. His sputum contained no tubercle bacilli, and an x-ray taken on November 20th, 1940, revealed no abnormality. He was examined on July 15th, 1943, when he was quite well, had no abnormal physical signs, and an x-ray of his chest revealed no abnormality.

**Case 6.** J. S., aged 45. He had worked on the roads and railways in Ireland, and for 10 years as a window cleaner in England before he started working on the shredding machine on October 12th, 1940. He continued to work on the machine until November 20th, 1940, when he was taken ill. He attended the Brompton Hospital on December 11th, 1940, complaining of severe shortness of breath, cough with much sticky purulent sputum, sweating, and loss of weight. On examination there were many scattered râles throughout both lungs. X-ray showed a diffuse soft mottling throughout both lungs with some confluent areas. He was admitted to the hospital from January 3rd, 1941 to February 19th, 1941, when he was found to have a low grade fever to 100 F., which quickly subsided. X-ray examination on February 19th showed that the changes had completely disappeared. On July 15th, 1943, he was well with no symptoms, no abnormal

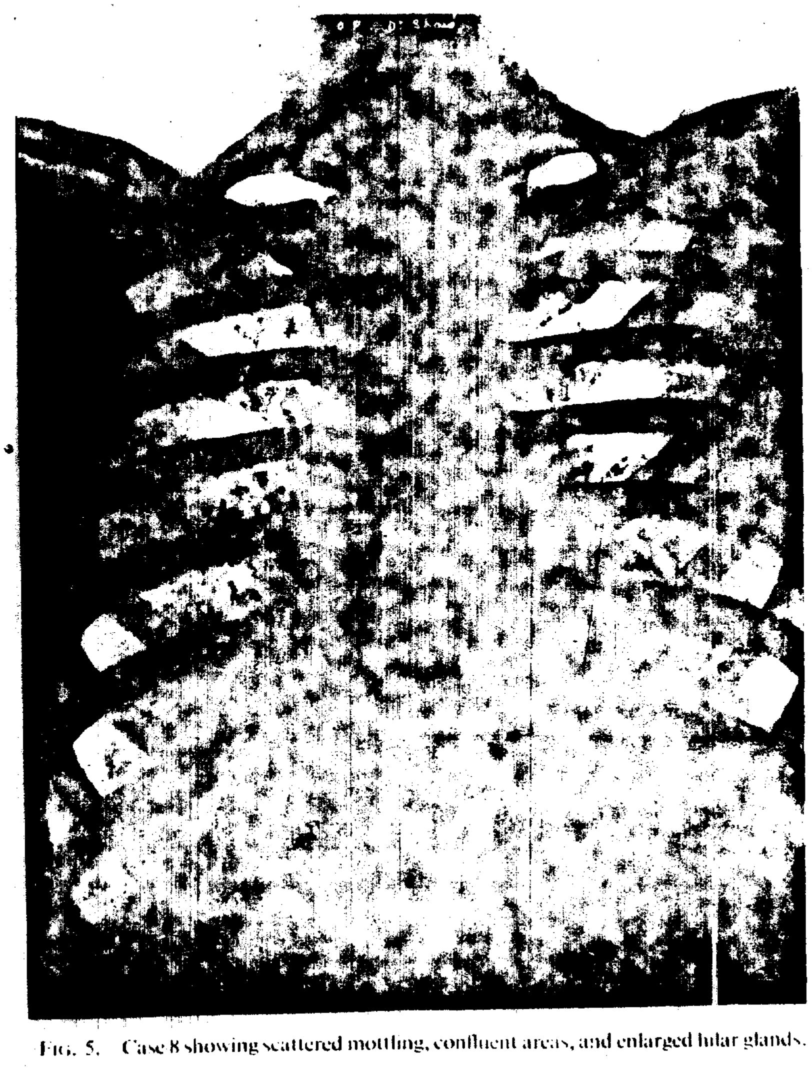

FIG. 5. Case 8 showing scattered mottling, confluent areas, and enlarged hilar glands.

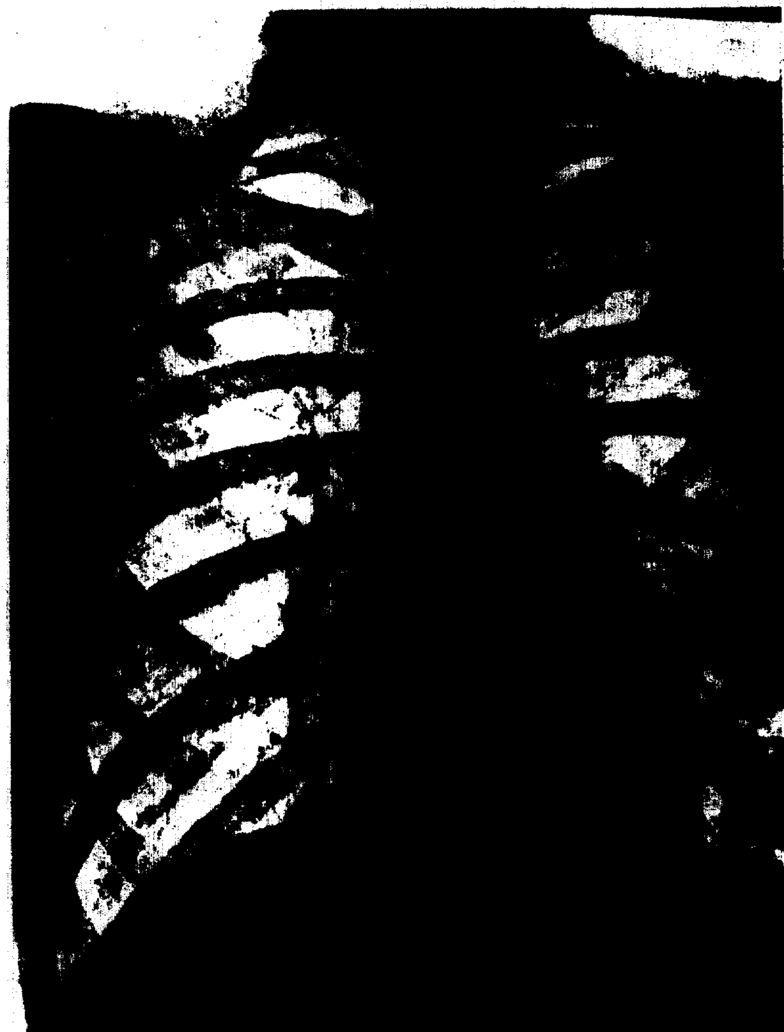

FIG. 6.—Case 8, three years after the acute illness.

physical signs, and there was nothing abnormal on x-ray examination.

Case 7. W. H., aged 38. He worked for 5 years as a collier's assistant in the South Wales coalfield, and for 15 years as a platelayer on the London, Midland and Scottish railway before joining the firm in October 1940. He worked from then until December 23rd, 1940, on the shredding machine when he was taken ill with fever, shortness of breath, cough with a small amount of sticky sputum, and loss of weight. He attended the Central Middlesex Hospital on February 27th, 1941, when he was found to have no abnormal physical signs. An x-ray was taken, and this revealed slight miliary mottling scattered throughout both lungs with enlargement of the hilar glands. On September 21st, 1943, he was in the Army. He had no symptoms, no abnormal physical signs, and x-ray examination of his chest showed no abnormality.

Case 8. E. P., aged 31. He worked in the motor engineering trade, in brickyards, and as a builder's labourer, before joining the firm as a labourer in October 1939. He worked on the shredding machine from September 1940 to January 25th, 1941, when he was taken ill. He attended the Northampton General Hospital under Dr. Eric Shaw on February 25th, 1941, complaining of cough with thick phlegm, shortness of breath, fever, and loss of weight. There were signs of consolidation at the base of the right lung. An x-ray showed scattered mottling throughout both lungs with some confluent areas and enlargement of hilar glands (fig. 5). He again attended on June 18th, 1941, when x-ray showed no abnormality. On July 4th, 1943, he still complained of much shortness of breath, cough and sputum, but an x-ray of his chest showed no abnormality in the lungs (fig. 6).

Case 9. W. W., aged 30. He had worked for a few months as an assistant collier in the South Wales coalfield, and then as a builder's labourer before joining the firm. He worked on the shredding machine from January 20th, 1941 to February 22nd, 1941, when he was taken ill. He was admitted to Wembley Hospital on March 6th, 1941, with severe shortness of breath and cyanosis. There were scattered patches of consolidation with bronchial breathing and coarse râles at both bases. On March 11th, 1941, there was a pleural friction rub over the right lower lobe. He was treated with oxygen at 6 litres a minute through a BLB mask, but the disease gradually spread and his condition deteriorated. He was considered to be too ill for x-ray examination, and died on March 19th, 1941. There was no necropsy.

**Case 10.** S. N., aged 21. (Case 1, Castleden and Hamilton-Paterson, 1942.) He had worked as a fish-boy and milk roundsman before joining the firm as a labourer on September 11th, 1939. He worked on the shredding machine from March 21st, 1941, to April 21st, 1941, when he was taken ill. He was admitted to Red-hill County Hospital under Dr. Castleden on May 4th with increasing shortness of breath and a cough with scanty sputum, sometimes blood-stained. His temperature was 100·6 F. on admission and he was febrile for 19 days. He was orthopnoeic and cyanosed: chest movement was poor, the percussion note was impaired, and there was distant bronchial breathing in small areas at both bases. The sputum contained M. catarrhalis, streptococcus viridans and fusiform bacilli. Staphylococcus aureus and pneumococcus Type 4 were each grown on one occasion. No tubercle bacilli were found. Blood count showed 4,610,000 red rells per c.mm., 78 per cent. haemoglobin, 11,300 leucocytes per c.mm., 83 per cent. neutrophils, 14 per cent. lymphocytes, 3 per cent. monocytes, and no eosinophils. X-ray on May 5th, 1941, showed extensive consolidation in both lower lobes with marked enlargement of the hilar glands. X-ray on June 15th showed some extension of the process, but on July 5th there was marked clearing, and by August 29th the lungs were completely clear. On August 27th, 1943, he was well and serving at sea with the Royal Navy. He had no symptoms, no abnormal physical signs, and x-ray of his chest showed no abnormality in the lungs.

In 1943 all the workers in the factory were interviewed and occupational histories taken. It was found that out of 163 men employed 22 had worked in the coal mines. A portable x-ray apparatus was taken to the factory and a skiagram (15 in. × 12 in.) was taken of the chest of all the workers. Of the 22 men who had previously been employed in the coal mines 19 showed evidence of chronic pulmonary disease, ranging through all stages of fibrosis, reticulation, nodulation and massive shadows. Three of these men, two showing fibrosis and one reticulation, had also worked on the shredding machine. These appearances could be superficially confused with those caused by bagasse, but whereas the latter is an acute febrile illness which clears in weeks or months, the former is a chronic state with no change over many years. Eight cases of pulmonary tuberculosis were also discovered.

Specimens of sputum obtained from the four men, who were working on the shredding machine at this time, were submitted to Duncan who isolated from them species of fungi common on the

FIG. 7.—Case 12 showing extensive fibrosis 3 years after working with bagasse.

bagasse and in the dust of the shredder room. Microscopical examination of the sputum did not reveal evidence pointing to mycosis, but showed the ingredients of the airborne dust. The fungal elements present, from which the cultures were obtained, represented merely the result of recent inhalation of dust.

In 1944 the men working on the shredder again had skiagrams taken of their chests. One man complained of symptoms and the skiagram revealed the characteristic picture described in the previous cases. Attempts were made to persuade him to come into hospital but he declined, and being a citizen of Eire he returned to that country. As far as is known he was afebrile. It seems possible, therefore, that the x-ray changes may precede the onset of the acute illness and be caused by bronchiolar obstruction, giving rise to small areas of collapse.

**Case 11.** J. S., aged 50. Started work at the age of 15 as a messenger boy. Apart from 6 years in the Army he had worked in a bacon factory, and on buildings in Ireland until 1943 when he came to England and started work at the board-making factory. For the first 6 months he worked on the beater floor in the main building and for the 6 months previous to examination he worked on the shredding machine. For 3 months he had had shortness of breath on exertion, a severe dry cough which was worse at night and in the early morning. He had a poor appetite and was losing weight. On examination no abnormal physical signs were found. A skiagram of his chest showed a diffuse miliary mottling throughout the lung fields.

A man who had worked part of three shifts on the shredding machine but had otherwise worked for a year at the far end of the factory, was discovered on x-ray examination to have bilateral fibrosis and possibly cavitation of an unusual type in both lungs. The x-ray appearances were similar to those of the electrical mechanic already referred to as working in the shredder room in 1940. Both men were admitted to hospital for further investigation. Their case histories were as follows:

**Case 12.** T. M., aged 38. (Case 2, Castleden and Hamilton-Paterson, 1942.) He had worked as a fitter until he joined the firm as an electrical maintenance mechanic. In this capacity he was intermittently in close contact with the dry crushing process during the installation of the new shredding machine between August 1939 and September 3rd, 1940, when he first complained of shortness of breath, cough and scanty sputum. His only previous illness was in 1935, when he was in Salisbury Infirmary for a few days with acute bronchitis.

FIG. 8.—Case 13 showing extensive pulmonary fibrosis.

A skiagram was not taken of his chest at this time. He attended the Willesden General Hospital in October 1940 and Dr. Rohan Williams reported on an x-ray of his chest. The appearances were consistent with a catarrhal bronchitis, but no further pulmonary lesion was noted. He returned to work in the office on October 30th, 1940, but was away sick with similar symptoms from November 22nd to December 10th, 1940. In December 1940 he began to be short of breath at work, and in January 1941 he was out of breath on the least exertion. On January 17th, 1941, he attended Redhill County Hospital under Dr. L. I. M. Castleden. He had clubbing of the fingers, and his chest was kyphotic with many fine râles in all areas of both lungs. X-ray showed a few apical scars and a little fibrosis in the right mid zone. In May 1941 he was admitted to Wembley Hospital where an x-ray was reported on as showing bilateral apical tuberculosis. The shortness of breath increased and he was admitted to Redhill County Hospital on November 22nd, 1941, and did not return to work at the factory handling bagasse. He was orthopnoeic but afebrile: the percussion note was impaired at the left apex with bronchial breathing and bronchophony. Crepitations were present throughout the left lung, and at the right apex. The sputum was mucoid, viscid, scanty, but never blood-stained. Polymorphs and lymphocytes were present. Haemolytic streptococci and pneumococci (type 23) were present. Tubercle bacilli were not found in the examination of 18 smears. A special search was made for fungi, but none were seen. A blood count showed 4,590,000 red cells per c.mm., 94 per cent. haemoglobin, 10,200 leucocytes per c.mm., 51 per cent. polymorphs, 32 per cent. lymphocytes, 6 per cent. monocytes, 11 per cent. eosinophils. X-rays showed extensive fibrosis in both upper lobes with multiple cavities. He was discharged on February 15th, 1942, with less dyspnoea. His condition remained unchanged and he was admitted to the London Hospital on August 16th, 1943, with orthopnoea and markedly clubbed fingers. There was poor movement of the left side of his chest with many scattered high-pitched rhonchi and râles. His sedimentation rate was 30 mm. in 1 hour (Wintrobe). His blood count showed 97 per cent. haemoglobin (alkaline haematin, photo-electric cell method) and 6,440 white cells per c.mm. X-ray of his chest (fig. 7) showed marked generalized fibrosis in both lungs and suggested the presence of cavities. His sputum showed no tubercle bacilli on smear, concentration, culture or guinea-pig inoculation. J. F. Duncan demonstrated the presence of *Candida sp.* On August 23rd Mr. Vernon Thompson performed a bronchoscopy which revealed no abnormality. He obtained bronchoscopic swabs from the pus present in the bronchi. No tubercle bacilli could be demonstrated in this pus either on smear, concentration, culture or guinea-pig inoculation. None of the fungi common in the sputum of men working on the shredding machine were found in the bronchoscopy specimens or any other specimens of sputum. The patient was treated with large doses of iodides without improvement, and discharged on November 27th.

He attended the out-patient department until September 23rd, 1944, when his breathlessness became very much worse, and he felt he had not the strength to cough up sputum. He was therefore admitted to hospital. On examination he was orthopnoeic, temperature 98°, pulse 110, respiration 32 at rest in bed. He was cyanosed and had a dry tongue with a brown fur and enlarged lymph glands in the upper cervical chain. There was a soft systolic murmur in the mitral area with a triple rhythm in the tricuspid area. His blood pressure was 105/70. Movement on both sides of the chest was poor and all accessory muscles of respiration were in play. There were palpable rhonchi over the front of the chest; percussion note was impaired at both apices; breath sounds were bronchial at both apices, but vesicular elsewhere. Coarse râles and rhonchi were heard all over the chest. His liver was felt 3 finger-breadths below the right costal margin. The sputum contained multiple organisms with streptococcus viridans and pneumococcus predominating. Blood count: 91 per cent. haemoglobin (photo-electric cell), 13,900 leucocytes, 90 per cent. polymorphs, 2 per cent. eosinophils, 7 per cent. lymphocytes, 1 per cent. large hyalines. X-ray of chest showed no marked difference from previous x-rays. His condition steadily deteriorated and he died on October 16th, 1944.

Necropsy revealed much thick pus and injection of mucosa in trachea and main bronchi. The posterior two-thirds of the upper lobe of the left lung was greatly contracted, airless, anthracotic and fibrotic, showing smooth rubbery, mottled grey and black cut surfaces and considerable bronchiectasis up to 0·5 cm. diameter with a few bronchiectatic cavities up to 1 cm. diameter. These cavities were empty and had smooth grey linings. There were thickened dilated bronchioles up to 0·3 cm. diameter throughout the anterior third of left upper lobe and throughout lower lobes of both lungs and right middle lobe, with much intervening well aerated emphysematous lung tissue. There were large areas of severe emphysema with emphysematous bullae in all borders of lower and middle lobes of both lungs. There were numerous irregularly shaped, grey and black mottled, tough mostly subpleural patches up to 3·5 cm. broad of completely fibrotic lung tissue with a smooth rubbery cut surface throughout the upper lobe of the right lung affecting all the lung tissue in the apex and almost all of the posterior fifth of the lobe, but with a considerable amount of well aerated intervening lung tissue in the rest of the lobe. Similar areas of fibrotic pneumonia formed an interrupted irregular subpleural zone 12 cm. long with depth varying from 0·2 to 1·2 cm. in the posterior part of each lower lobe, and also patches 1·5 cm. broad near the hilum of each lower lobe. Thick white pus was present in many bronchioles throughout both lungs. Numerous areas of fibrous thickening, up to 0·2 cm. thick, of the visceral pleura covered both lungs. Fibrous pleural adhesions obliterated both pleural cavities except over part of the left lower lobe.

Professor H. M. Turnbull is working on the pathology of the disease and when the work is completed will publish a full account of it in this journal.

**Case 13.** T. K., aged 42. He had worked on a farm and as a cellarman in Ireland before he joined the firm in July 1938. He worked in the packing department and on the 'defibrator' in the main factory, and on three occasions he worked part of a shift on the shredding machine. He complained of no symptoms, but in the mass radiographic examination of the employees on September 10th, 1943, he was found to have extensive fibrosis in the mid zone of both lungs (fig. 8). He was admitted to the London Hospital on November 23rd, 1943, and tomographs suggested the presence of cavities. Sputum examination revealed no tubercle bacilli on smear, concentration, culture or guinea-pig inoculation. Mr. Vernon Thompson performed a bronchoscopy on December 6th, 1943, and took swabs from the pus in the bronchi. Examination revealed no tubercle bacilli on smear, concentration, culture or guinea-pig inoculation. None of the fungi common in the sputum of men working on the shredding machine were found. The patient was discharged on December 8th, 1943, and his condition has not changed since then.

None of the fungi common in the sputum of men working in the shredding room were found in these two men's sputum. It may be presumed that when they and the other men were exposed to the dust of the shredding room, their sputum and probably the larger bronchi contained numerous inhaled fungus spores. We have no evidence of survival of any of the fungi in the lungs of men after removal from exposure to the atmosphere of the shredding room.

These two men were less exposed to bagasse than those who developed the acute infection described in cases 1–10; nevertheless they were exposed and their histories and clinical investigations are not typical of any known disease of the lungs. Case 12 had an acute respiratory illness at the commencement and though no skiagrams are available of his lungs at that time the natural chronic sequel to an acute bronchiolitis and pneumonia would be chronic bronchiolitis and bronchiectasis, and this is the condition that was found in his lungs at necropsy. Pathologically this chronic bronchiolitis and bronchiectasis does not differ from that arising in any chronic interstitial pneumonia, but the distribution in this case involving the upper lobe particularly posteriorly, and causing tough subpleural patches of fibrotic lung was most unusual except in the diseases caused by dust. It seems probable, therefore, that it was a chronic sequel to disease in the lung caused by bagasse.

The two cases reported by Jamison and his colleagues (1941 and 1944), the twelve cases reported by Sodeman and Pullen (1943 and 1944), and the ten cases reported here are all similar, and show almost conclusively that bagasse dust can give rise to acute bronchiolitis and pneumonia. Out of the 24 cases there were two deaths, a mortality rate of 4·3 per cent. Here, therefore, is an industrial disease with serious complications.

The exact aetiology of the disease, however, remains obscure. There are undoubtedly a great many fungi present in bagasse and Duncan has recovered similar fungi from men who have worked on the shredding machine, but there is no evidence that any particular fungus has caused the syndrome which is described: neither is there any evidence that the disease has been caused by any specific bacterium or virus. It is to be noticed that acid-fast bacilli were found in the sputum in case 5, and the case described by Jamison and Hopkins (1941). It is possible that the disease is caused by the irritation of the dust itself in the bronchioles, giving rise to an inflammatory reaction, but this hardly seems a satisfactory explanation.

Fungi may play an important role in breaking down the fibre into a very fine vegetable dust, and may possibly even render this toxic. Fawcitt (1938) has described a condition which he labelled 'Farmer's lung.' This disease is caused by inhalation of a fine vegetable dust from mouldy hay and in its symptomatology and radiological findings it closely resembles byssinosis as well as the condition described in this paper as caused by bagasse. A similar disease occurs in horses and is known as 'broken wind.' These four diseases so closely resemble each other that they may possibly belong to a single group with a common pathology.

Neal, Schneiter and Caminita (1942) described an acute febrile illness occurring among workers exposed to high concentrations of stained cotton dust. Although these authors attributed this disease to the presence of a gram-negative rod shaped bacterium, it is possible that this disease also resulted from the fine vegetable dust created in the process, or from the breakdown of vegetable matter by the organism described.

## Prevention

In the spring of 1941 the process of breaking the bagasse bales had been rendered wet by a spray of water to allay the dust. Exhaust ventilation was also installed. Since that period only one further case of the disease has been observed.

## Summary

An account is given of 11 cases of acute bronchiolitis and pneumonia arising from the inhalation of bagasse dust. One of these cases was fatal. Severe dyspnoea, cough with scanty sputum and occasional haemoptysis were the usual symptoms. There was a characteristic x-ray appearance which showed a miliary mottling scattered throughout both lungs with heavy shadows at the hilum.

Reference is made to 14 similar cases described in the literature, among which there was also one death. The aetiology is uncertain but the disease was most likely caused by fine vegetable dust. Two workers who had been in contact with the bagasse developed extensive fibrosis of lung, and one of these subsequently died. Necropsy revealed chronic bronchiolitis and bronchiectasis.

The method of prevention suggested is to allay dust and to handle bagasse in a moist state. Exhaust ventilation is also desirable.

## Acknowledgements

Our indebtedness to the many individuals and hospitals who have made this investigation possible is acknowledged throughout the text. We are also grateful to Drs. M. H. Jupe and D. Jennings for their help in interpreting the x-rays, and to Mr. H. Ferrier for carrying out the mass radiography.

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# BAGASSE

The crushed remnants of sugarcane stalks from which the sugar-containing juices have been extracted are known as bagasse. The term was originally applied to the refuse from olive oil mills in Provence, France, but it is now restricted to sugarcane residue. When sugarcane reaches maturity it is cut, the leaves are burned off, and the stalks are taken to mills where they are chopped or shredded and pressed by large rollers to extract the juice. The use of pressure rollers and water as a solvent results in the removal of 90–98% of the sucrose from the sugarcane; the fibrous material, bagasse, containing the crushed, chopped stalks and dirt, is left.

Bagasse varies in color but is generally a dirty-gray yellow to pale green. It is bulky and quite nonuniform in particle size. These variations are influenced by the variety of cane and the type of milling equipment. The bagasse from the most efficient mills is usually rather thoroughly broken up, and the particles average an





inch or less in length. The usual composition from the mill is about 45% insoluble solids or crude fiber, 6% soluble solids, and the remainder moisture.

## Properties

Physically, bagasse is composed of two distinct cellular constituents, the thick-walled, relatively long, fibrous fraction derived primarily from the rind and to a lesser degree from the fibrovascular bundles dispersed throughout the interior of the stalk, and a second pithy fraction derived from the delicate, thin-walled cells of the ground tissue or parenchyma of the stalk. The thin-walled pith cells in the living cane store the sucrose-containing juice; the objective of the mill operator is to rupture as many of these cells as possible to extract the juice they contain.

The approximate compositions of Hawaiian whole bagasse, the fiber fraction, and the pith fraction are given in Table 1 (1). Unfortunately no exact method of measuring the pith and fiber fractions in bagasse is available. Depending on the cane variety and, more particularly, on the diameter of the cane stalk, the pith content ranges from 35 to 45% by weight of the moisture-free bagasse.

The composition of the ash is important if the fiber is used for pulp. A high silica content will cause fairly high losses of caustic soda in the kraft or soda pulping processes; large amounts of iron and aluminum also complicate chemical recovery and may cause problems in bleaching; calcium may cause screen blinding on the papermaking machines.

Bagasse fiber is similar to cotton or wool fiber in that it has a spiral structure (2). The fibers vary from 1.0 to 4.0 mm in length and from 0.01 to 0.04 mm in width (3,4). The fiber dimensions vary with the kind of cane from which the bagasse is obtained (5). For comparison, Douglas-fir fibers average 5.0 mm in length and aspen fibers average 1.3 mm. Another important consideration for papermaking is the length-to-width ratio of the pulp fibers. The ratio for bagasse fibers varies from about 60 to 80, a ratio that is similar to that found for softwood fibers. Thus under ideal conditions paper made from bagasse fiber might approach the tensile strength, bursting strength, and folding endurance of paper made from softwoods (6).

**Health Factors.** The dust from bagasse that has been stored outdoors and become dehydrated and degraded from the effects of microorganisms, heat, and exposure is capable of producing a disease called bagassosis. Bagassosis, a respiratory disorder similar to pneumonia, was first recognized in 1937. It is caused by inhaling the dust; however, contact with fresh bagasse immediately after the juice-extraction process or freshly baled material has not, insofar as is known, produced disease. The disease is not completely understood at present, but it must be regarded as a potential hazard wherever stored bagasse is used for manufacturing (7).

## Uses

One of the uses of bagasse is as a fuel in the sugarcane factories. Since it is quite bulky and high in moisture, special furnaces are required. When burned efficiently it produces about 2700 Btu/lb; one ton of bagasse containing 49% moisture when burned with 100% excess air is about equal in fuel value to one barrel of fuel oil (8).

For bagasse to be used in manufacturing it must be stored varying lengths of time to provide a constant supply year-round. In the continental U.S., sugar mills operate for less than three months a year, thus large quantities of bagasse must be stored.

Kirk-Othmer Encycl Chem. Technol. 2nd Ed. 3: 36-40, 1964

**Table 1.** Chemical Analyses of Hawaiian Bagasse and Bagasse Fractions,[a,b] %

| Variety of sugarcane | Fraction | Solubility[c] | | | Pentosans | Lignin | Holo-cellulose | Corrected alpha-cellulose | Ash[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ether | Alcohol and benzene | Hot water | | | | | Total | $SiO_2$ | $Fe_2O_3$ and $Al_2O_3$ | Calcium |
| 44-3098 | whole | 0.3 | 3.5 | 2.6 | 27.1 | 21.6 | 76.0 | 38.7 | 1.63 | 0.75 | 0.33 | 0.10 |
| | fiber | 0.08 | 1.6 | 0.43 | 27.7 | 22.0 | 76.9 | 42.5 | 0.63 | 0.39 | 0.06 | 0.05 |
| | pith | 0.2 | 2.5 | 1.6 | 28.7 | 21.5 | 76.8 | 35.3 | 2.09 | 1.04 | 0.39 | 0.11 |
| 37-1933 | whole | 0.4 | 4.7 | 2.2 | 27.3 | 19.4 | 76.8 | 38.3 | 1.25 | 0.67 | 0.19 | 0.07 |
| | fiber | 0.08 | 1.7 | 0.36 | 28.4 | 20.3 | 77.7 | 42.1 | 0.82 | 0.52 | 0.15 | 0.06 |
| | pith | 0.2 | 1.9 | 2.6 | 28.8 | 19.5 | 78.1 | 34.3 | 1.83 | 1.05 | 0.22 | 0.18 |
| 38-2915 | whole | 0.4 | 3.6 | 2.4 | 26.4 | 19.4 | 78.3 | 38.8 | 1.96 | 0.88 | 0.47 | 0.08 |
| | fiber | 0.14 | 1.8 | 1.4 | 27.9 | 20.0 | 79.6 | 43.3 | 0.71 | 0.36 | 0.13 | 0.06 |
| | pith | 0.3 | 1.7 | 2.3 | 28.7 | 19.3 | 79.4 | 36.4 | 2.36 | 1.08 | 0.44 | 0.28 |
| 32-8560 | whole | 0.15 | 4.6 | 2.7 | 25.8 | 20.6 | 75.2 | 36.5 | 1.77 | 0.74 | 0.34 | 0.20 |
| | fiber | 0.18 | 2.1 | 1.4 | 27.5 | 21.0 | 76.9 | 41.9 | 0.66 | 0.28 | 0.09 | 0.06 |
| | pith | 0.3 | 3.0 | 1.0 | 27.6 | 20.6 | 76.6 | 33.1 | 1.87 | 0.96 | 0.38 | 0.17 |

Courtesy of *The Journal of the Technical Association of the Pulp and Paper Industry.*

[a] All data are on a moisture-free basis.

[b] Methods for the determination of pentosans, lignin, holocellulose, and alpha-cellulose are empirical; therefore, the analyses do not total 100%.

[c] Solubility data are a measure of the wax, fat, and sugar content.

[d] Ash content is of interest if the bagasse is to be pulped.

Conversely, in Hawaii the mills operate for 8–12 months a year, so little bagasse has to be stored and for but short periods of time.

As bagasse is a very perishable commodity, if it must be stored, special techniques must be used to preserve it. In the U.S. the bagasse is baled and stored outdoors in piles scientifically constructed to allow ventilation and drying, and it is treated in the pile with fungicides. The top of the pile is covered with metal sheeting to keep out rainwater. Naturally developed acetic acid fermentation during the early months of storage induces sufficiently high internal temperatures for effective sterilization, reduces sugar content, and renders the fibers more suitable for further processing.

In South Africa bagasse fiber is preserved by slurrying the mill-run material with water containing a patented culture of microorganisms. The bagasse is then stored in huge piles outdoors which are kept wet by recirculating the pile drainage. A process ensues which is similar to the retting of flax (see Linen), and it destroys most of the nonfibrous material. The fibrous residue is used for pulp production. A similar process employed by a Cuban pulp mill used ordinary river water.

The main problem bagasse presents to would-be users is the intimate association of the two fractions, the fiber and the pith. Most uses depend upon an economical method of separating the two parts for further independent processing. In the past the great difficulty of separation limited the use of bagasse to uses such as fuel; however, satisfactory methods of separation have now been developed (5,9). During the past decade a great deal of work has been done on bagasse utilization, including methods for the separation of the pith and fiber fractions. The process developed at Louisiana State University is now used in bagasse paper mills in Argentina, Brazil, Cuba, Egypt, and India. Another process (the Rietz method) developed by the Hawaiian Sugar Planters' Association and the Crown Zellerbach Corporation is used in Hawaii. Separation methods are not 100% effective and the material which is actually used in most of the bagasse pulp and paper mills is a mixture of fiber with some pith present. The pith, since it is nonfibrous, does not contribute substantially to the quality of the resulting pulp and does increase chemical consumption; consequently most bagasse users make it a practice to eliminate as large a percentage of the pith as is possible.

Several methods of depithing bagasse have been developed. They follow two general categories, wet and dry. In some systems the bagasse is first shredded or mechanically abraded to break the pith-cell clusters free from the fiber, and then it is screened. Other processes employ a continuous shredding and screening operation. Two methods (5,9) permit continuous separation of pith from mill-run bagasse containing about 50% moisture. Other methods require drying of the bagasse prior to depithing.

With separations involving a shredding or abrasion process followed by screening, the operation is difficult because of screen blinding. The methods previously mentioned for depithing (5,9) permit continuous separation either wet or dry; both have found some commercial acceptance. Keller (5) recommends an initial depithing of the mill run and the use of pith as fuel. The second and final depithing is done with water to remove solubles and to obtain a cleaner fiber. The bagasse fiber can be processed by any of the conventional methods. The fiber is very easily pulped and requires a rather gentle treatment as compared to that used for pulping wood and similar materials.

At present paper of various grades is being made from 100% bagasse in Argentina, Brazil, Cuba, Colombia, India, Egypt, South Africa, Puerto Rico, and the United States, to mention but a few.

Thus the development of an efficient method of separating the fiber from the pith has contributed to an important use for bagasse. The pith fraction resulting from the separation is used as a fuel and as an aid in juice filtration.

In the state of Louisiana about one-fifth of the total production of bagasse is used in the manufacture of structural and acoustical wallboard and other building products (10); bagasse is also used for this purpose in Hawaii, Australia, and Formosa. Other uses for bagasse are in the manufacture of agricultural mulch and litter (personal communication from L. Godchaux III, Godchaux Sugars, Inc.), and in plastics (11). Pith, due to its absorbent qualities, has been used in the manufacture of dynamite and as an absorbent for molasses in cattle feed.

A problem for the pulp manufacturer is the damage to the cane fibers by the juice extraction process; the macerating effect of the rollers breaks a large number of the fibers. Investigation of new ways to extract the juice which would not damage the fibers would be most profitable. Another area of research which would yield better papermaking properties is the development of new varieties of cane. Quite a variation in fiber length from one variety of cane to another now exists. Thus, if a new variety could be developed which would satisfy sugar production requirements but have greater fiber length, better papers could be made from the bagasse.

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# FATTENING OLD BULLOCKS—II. LEVELS OF ROUGHAGES AND MOLASSES AND THE EFFECT OF ADDING BAGASSE.

By

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(*Received for publication on* 12*th May*, 1962).

NATIONAL economy is always interlinked with the economy of the farm animals in a country. This is certainly no less true of Pakistan than of other nations. The value of livestock should be judged from their productivity. The present low production of Pakistan's livestock, among other things, is attributable in part to the fact that large numbers of animals are being maintained on too low a level of feeding (Ali, 1958). In Pakistan, cattle brought to slaughter houses are mostly victims of malnutrition and overwork. They are often very debilitated, hidebound in condition, and generally not suitable for human consumption. The meat thus obtained is of poor quality and possesses low nutritive value. This is the source of the beef eaten in this country. To increase the production of beef animals and thus add to the very stringent supply of human food and to increase the general production potentialities, it is desirable that before slaughter, old bullocks (oxen) be fed at a higher nutritive plane on easily-available, balanced and cheap feeds.

Commercial fattening of different kinds of livestock is not a common practice in this country. However, fancy fattening is sometimes observed, where people feed their animals lavishly on very costly feed stuffs, like gram, ghee (butter oil), etc. These animals are selected and kept for sacrifice for festive occasions. In doing this, the question of economy is totally overlooked. A successful attempt towards commercial fattening of sheep was first made in Pakistan at the College of Animal Husbandry, Lahore, in the year 1955. The purpose of this study was to find out efficient and economical rations suitable to the area (Ali *et al.*, 1956). Later, in 1958-59, fattening of old bullocks was successfuly carried out at the College (A. N. Scheme Prog. Rpt. 1960, Akram *et al.*, 1961).

This experiment on "Fattening Old Bullocks" was designed by the staff of the Animal Nutrition Scheme, College of Animal Husbandry, Lahore, and was conducted at the Gujranwala Sugar Mills, Rahwali, during the sugarcane crushing season, in order to demonstrate on the spot to the governing board and staff of the Mill, and to people in the surrounding villages, as well as to obtain data of value to the entire nation, the feasibility of fattening old bullocks with rations containing mostly ingredients that often are not considered good for cattle feeding. The objects of this research were to study the utilization of the byproducts

Part I has been published in "Agri Pakistan" Vol. XIII No. 1 1962.

Agric Pakistan
13(4): 89-108, 1962

of the mill, the molasses and the bagasse—as cheap, mill byproducts, together with other cheap local feeds such as rice bran, rapeseed (*toria*) oil cake, cottonseed cake, and rice straw in the villages and in a planned experiment in which old bullocks were fattened.

For 2 years, a committee assisted the Gujranwala Sugar Mills, Rahwali, in plans to market the molasses and demonstrate methods to other mills in the country. The committee consisted of personnel from the Mills, The Department of Animal Husbandry, The Village AID, College of Animal Husbandry, US AID, and Washington State University. This research and demonstration was financed by funds contributed both by the Animal Husbandry Department and by the Gujranwala Sugar Mills.

Before the start of the bullock-feeding experiment, a survey of the livestock feeding practices of farmers in Gujranwala and Wazirabad Tehsils was made. The feeds included in the rations used in this experiment, except for the molasses, baggasse and rice bran, were those commonly fed to cattle in the area.

**Review of Literature:**

Information on fattening of bullocks in this country (Lander, 1949) is scanty. Little or no research has been done on this subject. Most of the information on fattening cattle comes from western countries and thus mainly deals with younger animals. Also, many experiments in the United States, particularly, deal with the feeding of cereal grains, etc., that are not abundantly available for livestock fattening in Pakistan. However, Beeson and associates (1953) of the Indiana Agricultural Experiment Station developed a "Supplement A" for fattening cattle, especially designed to be fed at lower levels with low-grade roughages such as ground corn cobs, which also gave excellent results with some other poor roughages. This supplement, after modification, consisted of soybean oil meal 650.5 pounds, cane molasses 140.0 pounds, steamed bone meal 52.0 pounds, cobaltized salt 17.0 pounds and Vitamin A and D concentrate 0.5 pounds. Three and one-half pounds of this supplement per head daily were recommended for feeding with roughages.

Akram *et al.* (1960, 1961) of the College of Animal Husbandry, Lahore, in a fattening trial on old bullocks, found no significant differences when they compared cottonseed hulls with wheat straw, and maize grain with molasses. Protein was supplied by 40 per cent of undecorticated cottonseed cake (whole pressed cottonseed) in the rations. In their six groups, average grains of 1.5 to 2.7 pounds perhead daily were obtained.

A discussion of the different feeds included in the rations used in the present experiment follows:

In the proceedings of the Fifth Convention of the Sugar Technologists Association of India, 1936, Chaturvedi deplored the fact that although other countries fed huge quantities, hardly anything substantial had been achieved toward the utilization of molasses as cattle feed in India. Now, 26 years later in Pakistan, almost the same situation still exists.

*Molasses* can be fed as a supplement for pasture or in any ration requiring more energy. This results in more fat, better "marbling" of the flesh, slightly higher dressing percentages and higher carcass grades. In time of drought, when pasture forage is scarce, there is noticeably greater consumption of molasses, if it is available. Self-feeding cane molasses produces rapid gains and better finish (Skinner and King, 1915 ; Gerlaugh, 1930 ; King, 1931 ; Henke, *et al.* 1940 ; Wayman *et al.*, 1952 ; Scott, 1953 ; Wayman and Iwanaga, 1956 ; Poats, 1957).

In the Animal Nutrition Scheme, molasses in lamb fattening rations fed at levels of 8 per cent. and 16 per cent. compared favourably with maize grain (Ghauri *et al.*, 1962). In a former experiment with bullocks, the differences among maize, molasses and a mixture of maize and molasses are not significant. This is of economic interest, because of the wide disparity between the prices of maize and molasses (Akram *et al.* 1961, 1962).

The greatest value of molasses is an appetizer to encourage animals to eat unpalatable feeds and poor quality roughages. Molasses is a good source of energy, a carbohydrate feed that is greatly needed in the proper feeding of livestock in Pakistan, substituting for the cereal grains which are required for human food and cannot be used in large amounts in animal feeding. Suitably used, molasses could be the means for greatly increasing the production of the human foods of animal origin such as meat and milk. The literature pertaining to molasses has been amply reviewed in previous publications from the Animal Nutrition Section, College of Animal Husbandry, Lahore (Schneider, 1959 ; Akram *et al.* 1961 ; *ibid.* 1962 ; Ghauri *et al.* 1962).

Molasses can be fed on roughage placed in outdoor mangers (King *et al.* 1956). If diluted molasses is poured over unpalatable roughages, the consumption of such roughage can be increased (Olson, 1928). Molasses can be mixed with chopped or ground feeds. If very absorbent materials such as finely-ground, dried bagasse pulp are used and are brought into proper contact with warmed molasses, better blending occurs. The best results are obtained when molasses is substituted for up to 25 to 50 per cent of the carbohydrate concentrate, with provision for maintaining adequate nitrogen intake either by supplying adequate protein concentrate or by the use of urea (Heideman, 1954).

Mixing molasses with highly absorptive materials, if properly and thoroughly done, forms a dry, non-sticky feed that can be handled in bags or in bulk without the use of tanks. Molasses is too hygroscopic to be dehydrated, stored and fed in dry form without it being absorbed by some fibrous, finely-ground, dry base. Dried molasses is usually made by adding molasses to an absorbent material and then the bulk molasses feed dried in a drum or spray-drier (Heideman, 1954). Various carrying agents suitable for absorbing molasses include finely-ground, dried bagasse, bagasse pith (or pulp) lucerne meal, wheat bran, rice bran, hominy feed, beet pulp, soybean oil meal, palm nut meal, oat mill feed, groundnut hulls, sesame hulls, straw, chaff, dried blood, pulverized limestone, maize oil meal and maize germ meal (Halligan, 1909, Evvard, 1923). Molasses can be mixed 25 per cent and dried beet pulp 75 per cent (Scott, 1953). Undecorticated cottonseed cake (ground to a meal) is fluffy and will absorb a large percentage of molasses. Also, the cottonseed cake corrects the low protein content of the molasses. When finely-pulverized, dried materials are used, suitable mixtures containing more than 50 per cent molasses can be made, even up to 93 per cent molasses, wet basis equivalent. These must be packaged in laminated, moisture-proof, paper bags. It is important when such a bag is opened that all of its contents be used immediately. There are anticaking agents available, stearates and phosphates, etc., which delay or minimize caking and moisture pick up.

Bagasse, which is available wherever there is cane molasses, is a natural absorbent that should be thought of first. Sugarcane bagasse, remaining after as much as possible of the juice has been pressed out of the crushed stalks, is extensively used as a fuel at sugar factories. The smaller, pithy fragments screened out are called bagasse pulp. This pith or pulp, or the entire dried bagasse, may be used as an absorbent for molasses to facilitate the use of the latter in animal feeds. Although bagasse pulp is unpalatable, is can be used in small amounts without greatly decreasing the feed consumption. The presence of molasses tends to remedy this defect. However, bagasse cannot be considered anything more than a very poor quality roughage. Stock have been maintained in good condition on a mixture of sugar cane bagasse pulp, cane molasses and soybean oil meal. The dried bagasse and the dried pulp contain somewhat more fibre than straw from the small grains, but supply about as much total digestible nutrients as straw. Work (1937) gives the average T.D.N. content of sifted bagasse as 41.0 per cent. Bagasse pulp contains no digestible protein.

Chaturvedi (1936) reported on the manufacture of a sun-dried molasses absorbed on bagasse that had been sieved through a 25 mesh screen. A mixture containing approximately 25 per cent dried bagasse screenings, 25 per cent groundnut cake, and 50 per cent molasses was prepared. This mixed feed contained 10 to 12 per cent crude protein, 13 to 16 per cent crude fibre and 42 to 53 per cent. nitrogen—free extract. This mixture used in working bullock rations gave responses equal to those obtained with other standard rations used in India at that time (Schneider, 1937). It was proposed at that time that a bagasse-molasses mix, "bagomolasses," be sold to cane suppliers. Later, Ayyar and Zubery (1945) proposed an artificially-dried molasses feed composed of 3 parts of dried molasses and 1 part of finely-ground sugar cane bagasse pulp that was called "bagomolasses". When the moisture is removed, such a mixture leaves a free-flowing dried molasses product (Riggs and Blankenship, 1955).

In Hawaii, bagasse pulp has been used at 9 to 10 per cent of concentrate mixtures to permit the absorption of higher levels of molasses. It is stated that as much as 65 per cent molasses can be incorporated into a mixed feed containing this amount of dried, finely-ground bagasse pulp and that such mixed feed is non-sticky and free-flowing (Wayman *et al.* 1952; Wayman and Iwanaga, 1956). Dehydrated and finely-ground bagasse pith or pulp may absorb as much as 90 per cent of its own weight in molasses. When properly handled, bagasse pulp will absorb far more molasses than almost any other commonly known feed ingredient (Fairbank and Tavernetti; Richardson, 1953; Karstens, 1954, Heideman, 1954).

In a previous experiment in the Animal Nutrition Section in which finely-ground bagasse pulp was substituted for an equal amount of cottonseed hulls in sheep rations at the level of 9.5 per cent, the average daily gains in body weight averaged less than 0.2 pound per day while identical rations in every way except for this substitution gained about 0.33 pound per day (Animal Nutrition Scheme Rpt., 1960; Ghauri *et al.*, 1962). The rations containing bagasse pulp significantly depressed the rate of gain below those not containing it. Hawaii experiments have indicated a difference between fresh bagasse pulp and older, deteriorated pulp. It is possible that the pulp used in this experiment was not sufficiently fresh. However, bagasse pulp cannot be expected to be more than a poor to fair roughage. The differences in the rates of gain in this lamb fattening experiment with rations with and without bagasse pulp are striking.

Rice growing and cattle production go well together. In some countries, rice is not grown on the same land year after year, but may be grown in rotation with pasture or forage crops. Maintaining cattle in rice areas utilizes the rice straw, rice stubble, second-growth rice and the milling by-products of rice.

Rice straw is usually considered to be a very coarse, woody and inferior roughage. It is somewhat less nutritious than oat straw or barley straw. Good rice straw has about 90 per cent of the nutrients contained in good grass hays. However, large quantities of rice straw are available and are fed to cattle and buffaloes in Pakistan. It is a staple roughage for cattle in many rice-growing districts. It is low in calcium content (0.2 per cent) and phosphorus (0.07 per cent). If fed to cattle, its deficiencies must be met by feeding it with other feeds that supplement it. For instance, it should be fed together with some green forage to supply the necessary carotene. Rice straw is an economical roughage when supplemented with small amounts of lucerne hay and minerals (Snell *et al.* 1945).

In a previously-published bullock-fattening experiment conducted in the Animal Nutrition Section, Athar *et al.* (1962) were unable to demonstrate any significant differences in body weight gains or in the amount of feed required to produce 100 pounds of body weight gain between rations containing cottonseed hulls or rice straw as the principle roughage.

Some persons have recommended washing rice straw, soaking it and draining off the water, to improve its quality. Also, an alkali treatment has been advocated (Kehar, 1953).

In East Pakistan, the rice known as *Aus* is sown in March and April and harvested in June and July. Summar rice is known as *Boro* and winter rice is called *Aman*. *Aman* may be classified into two types deep water and transplanted rice. Deep water *Aman* is sown in April or May and harvested in November. Transplanted *Aman* is planted as seedlings in September. It is harvested in November or December. The straw of deep water *Aman* is generally coarser than the transplanted type. As a consequence, its palatability and nutritive value are thought to be less than that of the transplanted type. *Aus* rice straw is greener at harvest than *Aman* straw. Therefore, it is generally thought to be softer and more nutritious than either *Aman* or *Boro* straw, and cattle prefer *Aus* to *Aman* straw. Research indicates that *Aus* rice straw has a greater nutritive value for cattle than *Aman* straw, the former being richer in protein and calcium. It has been recommended that it be supplemented by feeding one-half pound of linseed oil cake per animal daily (Chatterjee and Hye, 1938).

When rice straw is fed to breeding cows plus 3 pounds of a mixture of rice mill byproducts (rice bran and rice polish) and cottonseed meal, these supplements reduce death losses and increase the calf crop. Feeding these concentrates in winter with rice straw increases the birth weight about 5 pounds per calf and produces calves about 18 pounds heavier at weaning. With rice straw alone and pasture, the calves average 67 per cent of the birth weight of those produced by cows receiving the concentrates in addition during the winter feeding. Good calves may be raised by strong cows wintered on rice straw without extra feeding, but additional care should be taken for weaker cows and young heifers that are pregnant during feed shortages and cold weather (Snell *et al.* 1944).

Rice straw together with molasses can be used as a supplement to semi-tropical pastures during the dry season when there is limited grazing (Macahilig, 1939).

*Rice bran* is the pericarp or bran layer of the rice, with only such quantity of hull fragments as is unavoidable in the regular milling of rice (Assn. Am. Feed Control Officials, 1960). It is the principle by product of the rice milling industry. Bran represents about 8.5 per cent of the rough rice, and is a low-priced feed, medium in protein content, high in fat and high in phosphorus, but low in calcium. Although it contains less T.D.N. than cereals, its value rates higher than this when fed in suitable mixtures (Maynard *et al.* 1923 ; Kik, 1942).

Rice bran has a higher fat content that wheat bran and the fat is somewhat oily. It has an oil content of about 14 to 17 per cent. Its high percentage of oil is mainly responsible for rice bran becoming rancid in hot weather. There is a tendency for the oil in the bran to undergo rapid hydrolysis to free fatty acids and glycerol, with resulting rancidity (Pominski *et al.* 1954). This makes it unpalatable and its feeding value deteriorates with age (Texas Agr. Exp. Sta. Bul. 182). If the rice grain is thoroughly dried before milling, this produces not only better rice but also better bran. Unless it is thoroughly dried, because of its high fat and moisture content, it is more likely to become rancid and mouldy and to cake, especially during hot weather. Thus, unless this feed has a low moisture content, it is necessary that it be fed only in the fall and winter immediately after production. Sometimes, to avoid the possibility of rancidity, part of the oil is removed from rice bran by the use of solvents. Also, an antioxidant such as calcium carbonate may be added to rice bran to prevent excessive rancidity developing.

Morrison (1956) gives the digestible protein content as 8.4 per cent and the total digestible nutrients of rice bran as 67.4 per cent, but when the high-energy fat is solvent-extracted the digestible protein content is 9.7 per cent and the T.D.N. is 55.3 per cent. The Association of American Feed Control Officials, Inc. (1960) stipulates that rice bran should have not less than 12 per cent total crude protein or more than 12 per cent crude fibre.

Low grade rice bran may contain a large amount of rice hulls. The percentage of fiber will indicate the proportion of hulls. Rice bran with 8 per cent fiber contains little or no hulls, 10 per cent fiber indicates about 6 per cent hulls and 15 per cent fiber indicates over 20 per cent hulls. Rice bran has about 88 per cent of the value of maize grain when fed as the main concentrate source (Robison, 1939; Bray, 1943).

It appears that rice bran can more profitably be fed to milking cows and poultry than to beef steers (Snell *et al.* 1945). For milk production in dairy cows, rice bran is worth, in digestible nutrients, about 5 per cent more than wheat bran and from 75 to 80 per cent as much as ground maize. Fresh rice bran seems to be as palatable as wheat bran and when it does not make up more than one-third of the concentrate mixture (Sheets and Semple, 1931). When rice bran is fed together with cottonseed meal, somewhat poorer results are obtained with milking cows than when wheat bran is fed with cottonseed meal. Rice bran is not a good feed from the standpoint of maintaining body weight when fed with maize silage. The addition of maize bran to a concentrate mixture of rice bran and cottonseed meal appears to improve it so that somewhat better results are obtained with this type of mixture than when wheat bran is fed. With wheat bran and cottonseed meal, 100 pounds of dry matter produces 0.5 pound more milk and 0.13 pound less butterfat than does the same amount of dry matter in the rice bran-cottonseed meal mixture (Emery and Johnson, 1899). Rice bran may be used in proportions of 25 to 40 per cent in concentrate mixture for dairy cows without affecting the palatability of the ration or injuring the health of the animals. There is little or no effect on the butterfat of the milk. Rice bran, provided it is fairly pure and not fermented, is an excellent and economical feed for dairy cows. From 2 to 3.3 pounds per cow daily has no ill effects on the health of the animals even during the hot season (Bonadonna, 1936; *ibid.*, 1937).

Good gains may be obtained by feeding steers on rations consisting primarily of rice byproducts if properly used (Snell *et al.* 1945). When fed as the only concentrate other than the protein supplement, rice bran is not entirely satisfactory for fattening steers, showing a value of only 64 per cent to 68 per cent of the value of maize grain. Steers fed principally on rice bran sell at a lower price per pound and make the lowest gains per day. Better advantage is obtained with a combination of rice bran with maize or molasses (Snell *et al.* 1945). More gain, with less feed required per 100 pounds of gain was obtained from steers fed a ration in which rice bran replaced 25 per cent of the ground shelled maize, in comparisons with rations containing no rice bran or in which rice bran replaced 40 per cent or 50 per cent of the maize. When rice bran was fed in too large amounts, the cattle had a tendency to go "off feed". There was no difference in the carcass desirability of the steers (Jones *et al.* 1935).

Combinations of rice products such as rice bran and rice polish with molasses have from 80 to 90 per cent of the value of maize grain in fattening steers. Such cattle finish satisfactorily and show comparatively little difference in dressing percentage and carcass grades from maize-fed animals, but the average daily gains of maize-fed animals exceed them (Snell, 1940).

Although the response has been poorer in some beef cattle experiments in which rice bran was fed, in others a decided advantage from feeding this feed has been observed. When rice bran was fed with silage and cottonseed meal, as a fattening ration for 2 year-old steers, gains were lower than when a ration of cottonseed meal, silage and ground milo (a sorghum like *juar*) heads was used. The ration containing the mild seemed to be more palatable than the one containing rice bran (Texas Agr. Exp. Sta. Bul. 182). However, in another experiment, rice bran was worth about 10 per cent more than ground milo heads as a supplement to silage and cottenseed for fattening steers (Sheets and Semple, 1931).

Rice bran may be substituted for part of ground milo and cottonseed or for part of ground shelled maize in a ration, often giving increased gains and greater profits. Gains may be increased and the cost of gains decreased when dehydrated rice bran replaces 25 to 40 per cent of the concentrates in rations for fattening steers. These results were obtained in 3 feeding trials when rice barn was used to replace a part of the threshed milo, ground threshed kafir (both sorghums like *juar*) or ground shelled maize as the grain portion of cattle fattening rations. Also, cattle receiving 20 to 25 per cent of rice bran have made distinctly higher gains than those receiving maize grain alone. Although rice bran may be substituted for as much as 50 per cent of the grain in the ration with no decrease in rate of gain, maximum returns usually may be obtained from rice bran when it is fed to replace 25 to 30 per cent of the grain portion of a cattle fattening ration (Craig and Marshall, 1904; Knox *et al.* 1933; Texas Agr. Exp. Sta. Ann. Rpt. 1934; Jones *et al.* 1935).

*Toria* oil cake is the residue remaining after pressing the oil out of winter or Indian rape (*Brassica napus* var. *dichotoma*). It is a cheaper oil cake than cottonseed cake but is somewhat unpalatable to livestock because of its sharp bitter taste, especially when fed in large quantities. It is a good source of total digestible nutrients, digestible protein, calcium and phosphorous. When fed in moderate amounts no harmful effect is observed with cattle (Richer, 1934; Bunger, 1936; Nutr. Abstr. & Revs., 1936; Burkitt, 1951).

In an experiment in the Animal Nutrition Section, Ahmad *et al.* (1962) found *toria* oil cake quite unsatisfactory as the sole protein supplement in lamb-fattening experiments. Some lambs fed *toria* oil cake did not gain any weight at all in 98 days of feeding.

Whole pressed cottonseed, or *undecorticated cottonseed cake*, is the product resulting from subjecting the whole, sound, mature, clean, undecorticated cottonseed to pressure for the extraction of the oil, and includes the entire cottonseed less the oil extracted and the lint removed. Its protein content is lower and the fiber content higher than in decorticated cottonseed cake or meal. Undecorticated cottonseed cake has been used extensively in Pakistan for many years. It was advocated to replace the feeding of whole cottonseed by Lander in 1929 (Lander and Dharmani 1929). It is stated that the feeding of cottonseed cake actually became a reality in this area in 1937 (Hussain and Ahmad, 1957).

Cottonseed cake is one of the best protein supplements for cattle and sheep according to a number of workers (Kennedy *et al.* 1910; Read *et al.* 1928; Huffman and Moore, 1929; Halverson and Sherwood, 1930; Lander and Dharmani, 1944; Holley *et al.* 1955). In comparision with guara (*Cyamopsis psoraloides*) grain, it requires 4 pounds of undecorticated cottonseed cake for the same efficiency as 2.5 pounds of guara grain (Hussain and Ali, 1949). Cottonseed cake is also a good substitute for gram (Chickpea, *Cicer arietinum*). For the sake of economy, it is certainly desirable usually to feed cottonseed cake instead of gram (Hussain and Ahmad, 1957).

**Experimental Goals, Methods and Animals**

The experimental work reported in this paper was for two purposes:

1. To test the resistance of village people to the introduction of a new idea, *i.e.*, the feeding of molasses and|or bagasse.

2. To experiment openly before them with rations containing molasses and bagasse and to demonstrate the use of these feeds.

To help achieve the first purpose, Gujranwala and Wazirabad Tehsils were surveyed with the object of collecting information regarding livestock feeds and feeding practices. A Veterinary Hospital was taken as a survey unit represented by at least 6 villages, one in each direction if possible and not very far off from the hospital. From each village, as many farmers were questioned as were willing to cooperate. Eighteen villages and 123 persons from Gujranwala Tehsil and 26 villages and 125 persons from Wazirabad Tehsils were questioned. Following this, the staff of V-AID, Agriculture, Animal Husbandry, the Gujranwala Sugar Mills and US AID put on demonstrations in key villages throughout the Gujranwala and Wazirabad Tehsils, the area served by the Sugar Mills, on the mixing of cattle rations containing sugar cane bagasse, and molasses. Two bulletin boards at the mill and "wall newspapers" for use in the villages were prepared. Also, the bulletin, "Using Molasses as an Animal Feed" (Schneider, 1959) was written as a source book to correctly inform mill owners, managers, Government officials and the general public on molasses handling, storage, distribution, feeding, etc. It was hoped that reporters would use this material for short, popular articles on molasses in the English and Urdu newspapers.

Twelve old bullocks were purchased from Hafizabad and Kamoke cattle fairs and were brought on foot to the sugar mill, Rahwali, Gujranwala. They covered the nearly 30 miles on foot. After their arrival they were dewormed with two ounces each of hexachlorethane drench. They were numbered from 1 to 12 and were randomly assigned into four groups, each consisting of three replicates on the same ration. They were weighed weekly till the expiry of the experiment. They were fed for a preliminary period of 41 days, after which the body weights were taken as the initial weights. From this date onward, they remained under experimentation for 133 days.

Records were kept of the following :

1. Weekly weights.
2. Amounts of feed given, refused and consumed daily.
3. Amounts and kind of green feed consumed daily.
4. Health of the animals.

**Management and Feeding Practices:**

The bullocks were housed in a cattle shed outside the Gujranwala Sugar Mills, Rahwali. The weather was very cold and the shed was very drafty, so the animals were covered during the night with *jhools* (blankets) made out of gunny bags, to protect them from severe cold. Later in the experiment when the nights became warmer, this was not necessary. During the day the animals were taken out of the shed in the warm sun and cleaned and groomed. Saw dust from a nearby factory was used for bedding.

Twelve cement portable mangers for individual bullock feeding were taken to Rahwali from the Animal Nutrition Section, College of Animal Husbandry, Lahore. A cement platform was made on the premises for the hand mixing of rations. Each ration was prepared 100 pounds at a time. The information gathered in the preliminary survey regarding the common feeds of the area was considered in making up the rations used in the experiment. Rations believed to be suitable for a sugarcane-rice growing area were planned. The rice straw was first chopped in a chaff cutter, then weighed and mixed with weighed quantities of molasses, rice bran, crushed cottonseed cake and rapessed (*toria*) oil cake, sifted bagasse pulp, ground limestone and pulverized salt. Bagasse pulp was substituted for the rice straw at a level of 10 per cent of the ration to see if it could be substituted for an equal amount of the rice straw, thus aiding in the absorption of molasses, and utilizing an even cheaper roughage than rice straw. The bagasse pulp or pith used in this experiment was prepared by passing the finer parts of the bagasse through a sieve. The coarser, more fibrous, woody, outer portion of the sugar cane stalk or bagasse was thus removed and discarded.

In the judgement of the supervisor and the cattle attendants, *toria* oil cake was believed to be too unpalatable to be fed at a level of 20 or 25 per cent in the rations. Therefore, even when *toria* oil cake was cheaper than cottonseed cake, the latter was used to supply half of the protein supplement used in the ration. Ground limestone was fed at a level of 0.6 per cent of the ration, as otherwise the amount of calcium in proportion to the phosphorus did not appear to be adequate.

The animals were fed twice daily at 5 a.m. and 4-30 p.m. The amount of ration offered to each bullock varied throughout the experiment, starting with a minimum and then being gradually increased. The bullocks were weighed early in the morning before feeding or watering every week on the Mill's weighbridge. The four rations and groups of animals were designated as A, B, C and D, there being three bullocks per ration. The four rations are shown in Table I. In addition each animal received 3 pounds of green feed (berseem) daily. This supplied their carotene requirements. Also, weighed pieces of rock salt were placed in the mangers for licking. The bullocks were watered three times daily. The assumed nutrient composition of the feed ingredients and experimental rations is shown in Table II.

TABLE I

*Bullock Fattening Rations*

| | Rations A | B | C | D |
|---|---|---|---|---|
| | Lbs. | Lb. | Lb. | Lb. |
| Rice straw | 40 | 30 | 25 | 15 |
| Bagasse pulp | .. | 10 | .. | 10 |
| Rice Bran | 20 | 20 | 25 | 25 |
| Cottonseed cake (undecorticated) | 10 | 10 | 12·5 | 12·5 |
| Rapeseed (*toria*) oil cake | 10 | 10 | 12·5 | 12·5 |
| Molasses | 20 | 20 | 25 | 25 |
| Ground limestone | 0·6 | 0·6 | 0·6 | 0·6 |
| Salt | 0·2 | 0·2 | 0·2 | 0·2 |
| Total | 100·8 | 100·8 | 100·8 | 100·8 |

TABLE II

*Assumed Composition of Ingredients and Rations*

| | *Dry Matter %* | *Dig. Protein %* | *T.D.N. %* | *Ca. %* | *P %* |
|---|---|---|---|---|---|
| Rice straw | 92·5 | 0·6 | 41·5 | ·19 | ·07 |
| Bagasse pulp | 90·3 | .. | 41·0 | .. | .. |
| Rice bran | 88·0 | 8·2 | 63·0 | ·14 | 1·36 |
| Undecorticated cottonseed cake | 92·0 | 18·0 | 63·8 | ·18 | ·52 |
| Rapeseed (*toria*) oil cake | 93·6 | 26·9 | 61·3 | ·93 | ·95 |
| Molasses | 74·0 | .. | 60·0 | ·66 | ·08 |
| Rations: | | | | | |
| A | 88·76 | 6·37 | 55·74 | ·947 | ·463 |
| B | 88·51 | 6·31 | 55·69 | ·928 | ·456 |
| C | 88·37 | 7·81 | 59·30 | ·986 | ·561 |
| D | 87.12 | 7·75 | 59·25 | ·967 | ·554 |

Graphs showing weekly weights of these animals were maintained. The design of the experiment was a 2×2 factorial consisting of a total of four groups.

**Results an Discussion:**

The results of the bullock feeding are summarized in Table III and the economic aspects of the experiment can be adjudged from Table IV.

**TABLE III**

**Summary of Weight Gains and Feed Consumption of Bullocks**

| *Rations* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| Number of bullocks | 3 | 3 | 3 | 3 |
| Average initial weight | 775·3 | 744·3 | 693·6 | 741·0 |
| Average final weight ,, | 897·0 | 1036·0 | 827·3 | 889·0 |
| Days on feed ,, | 33 | 133 | 133 | 133 |
| Average total gain per bullock ,, | 121.7 | 291.7 | 133.7 | 148.0 |
| Average daily gain per bullock ,, | 0·91 | 2·91 | 1·05 | 1·11 |
| Feed required per 100 lb. gain ,, | 2472·8 | 1240·2 | 2114·8 | 2160·4 |
| Average daily feed per bullock ,, | 22·6 | 27·2 | 21·2 | 42·4 |
| Rice straw daily ,, | 8.96 | 8.09 | 5.27 | 3.66 |
| Bagasse pulp daily ,, | .. | 2·69 | .. | 2·44 |
| Cottonseed cake daily ,, | 2·24 | 2·69 | 2·63 | 3·05 |
| Rapeseed (*toria*) oil cake daily ,, | 2·24 | 2·69 | 2·63 | 3·05 |
| Molasses daily ,, | 4·48 | 5·38 | 5·27 | 6·10 |
| Limestone daily ,, | 0·13 | 0·16 | 0·12 | 0·44 |
| Salt daily ,, | 0·4 | 0·5 | 0·4 | 0·4 |

**TABLE IV**

**Financial Summary of the Experiment**

| Rations | Cost of Ration per maund of 82·29 lbs. | Ave. cost of feeding for 133 days | Ave. cost of feed per day | Ave. daily gain | Ave. cost per pound of gain |
|---|---|---|---|---|---|
| | Rs. | Rs. | Rs. | lb. | Rs. |
| A | 3·84 | 147·97 | 1·11 | 0·91 | 1·22 |
| B | 3·84 | 176·36 | 1·33 | 2·19 | 0·61 |
| C | 4·27 | 153·91 | 1·16 | 1·05 | 1·18 |
| D | 4·27 | 173·95 | 1·31 | 1·11 | 1·17 |

Analysis of variance showed statistically significant differences (at the 5% level) in mean gain in weight. Orthogonal analysis revealed highly significant greater gain and final weights (at the 5% level) between the gains of the bullocks on Ration B and those fed the other rations. Duncan's multiple range test to compare the means also showed significant differences between Ration B and Rations A, C and D.

The analysis of variance, orthogonol analysis and Duncan's multiple range test to compare the means, revealed no statistically significant differences in the mean feed intake per 100 pounds of body weight gain between any of the rations in the experiment.

The statistical comparison of the rations (A and B) containing 20 per cent molasses versus rations (C and D) containing 25 per cent molasses showed no significant differences in mean gain in weight and feed intake per 100 pounds of gain in weight.

Several of these animals were in a very poor state of health when purchased. Thirty miles walk to Rahwali further told upon their health rather badly. As a result, a few of them died later due to exhaustion. These had to be replaced by others during the preliminary period. Some of them continued in poor health and it was necessary to treat them for indigestion or to give them a tonic. These animals varied greatly in thriftness and in initial body weight (from 576 to 799 pounds). Although it was the intention to fatten decrepit bullocks, some of these particular animals were more debilitated than was desired. Thus, there were no significant differences in their body weight gains that can be attributed to differences in the rations. These facts are important, however, that such **old bullocks, accustomed to eating low-quality roughage, make essentially as good gains with rations containing 40 per cent roughage as with those containing 25 per cent roughage.** Also, those bullocks in whose rations 10 per cent sifted bagasse was substituted for an equal amount of rice straw showed no significant differences in gains. In fact, the ration that might be chosen as the poorest (being highest in roughage and containing sifted bagasse—a very poor quality feed) gave the most favourable response because two of the three animals on this ration happened to be the most thrifty individuals in the experiment. It can be concluded that in this experiment "individuality" played a larger part than did the kind of ration and that the differences in the rather diverse rations were not great enough to overcome this "between animal" variability even when they were all full fed.

Feeding of these products did not have any untoward effect on the health of the animals and the farmers of the *ilaqa* (locality) who saw the animals before and after the experiment were fully convinced that molasses not only can safely be fed to any kind of livestock, but also that it is one of the cheapest substitutes for grains. Feeding it can result in considerable financial saving. In the vicinities of sugar mills, molasses can be purchased for one-tenth of the price of maize grain and other grains or carbohydrate feeds. Consumption of coarse forages can be increased by mixing molasses with them. Similarly, bagasse, which is used as a fuel in sugar factories, can be obtained for a very low price. Quite satisfactory results were obtained with its inclusion at a 10 per cent level in these rations. This has further reduced the cost of fattening these bullocks and the gains obtained were very economical. In a previous study (Animal Nutrition Scheme Rpt., 1960; Ghauri et al. 1962), bagasse showed a depressing effect on the gains of sheep when it was added at approximately the same level, thus indicating that there might be a species difference in the utilization of this material. It may also be noted that the cost of fattening of these animals was reduced further by substituting part of the cottonseed cake with rapeseed (*toria*) oil cake. Cottonseed meal was the most expensive ingredient in the ration; all others, including rice straw, bagasse rice bran, *toria* cake and molasses, being relatively cheap in price.

The average initial cost of each bullock was Rs. 60.00, while the average sale price was Rs. 173.42. Under rural conditions the fattening of animals may be expected to be cheaper than in big cities where prices of feedstuffs are relatively high. An example of what is possible with such an economical fattening ration is that of Bullocks 4 and 8. These animals weighed 768 and 799 pounds, respectively, in the beginning, and at the end of the experiment weighed 1117 and 1104 pounds, respectively. In 133 days of feeding they gained 349 and 305 pounds each, with daily average gains of 2.6 and 2.2 pounds each. They ate an average of 27 pounds of feed daily (Ration B) at a cost of Rs. 1.32 per day. The sale prices of these two animals were Rs. 265.00 and Rs. 255.00, respectively. This shows that fattening can pay rich dividends if undertaken properly. After this feeding period, these bullocks possessed such a strong physique that they might well be used for ploughing work for another two to three years.

The main object in fattening should be the improvement in the quality of lean meat and not the storage of thick masses of fat. During fattening, fat is stored in the lean tissues, chiefly between the muscle fibres (marbling). This, besides increasing the digestibility and nutritive value, adds juiciness and flavour to the meat. The meat from fattened animals usually becomes much more tender. There are various factors which affect fattening each as age, size and breed of the animal. Younger animals usually make much more rapid and economical gains, and require less feed per 100 pounds of gain. Before undertaking fattening of animals, one must be very careful regarding the purchase of animals. Slight slackness or a mistake in the selection of animals may reduce the chances of profit because of deaths or unthriftness. There is an old saying among stockmen, "A better purchased animal is half sold."

It was clearly demonstrated that feeds such as molasses, sifted bagasse pulp, rice straw and rice bran can be used in the fattening of old bullocks. There are some prejudices about all these feeds. Molasses feeding has been considered to be very harmful to animals. Rice straw is regarded as a very inferior roughage for animals and hence is fed most during winter scarcity. Similarly, rice bran is thought to be not a good feed for cattle; it is usually fed only to donkeys.

In the preliminary survey, it was revealed that previously only 3 persons in Gujranwala and 1 in Wazirabad Tehsil had ever fed molasses or gur to animals. On the whole, reaction toward feeding gur (crude, village-produced sugar) was more favourable than towards molasses.

Village men thought that molasses, being a by-product of the sugar industry, might have some chemicals that would be harmful to live-stock. In spite of this prejudice some people from every village expressed willingness to try it. In one survey sub-committee meeting with the city milk producers of Gujranwala, it was discovered that the cost of the concentrate mixture fed to buffaloes was too high in comparison with the sale price of the milk. Certainly molasses can be used to reduce the cost of the rations that are fed.

Over 100 demonstrations were given in the villages of Wazirabad and Gujranwala Tehsils. It was adequately demonstrated that village people would respond to the merchandizing of molasses and would buy it if it were made available to them. After the bullock feeding trial and the village demonstrations were completed, many more expressed interest and the desire to feed molasses. The Government Agricultural Station at Gujranwala started to use molasses and has been feeding it to working bullocks ever since that time. Also, this Station cooperated with the Animal Nutrition Section in an experiment on feeding molasses to working bullocks (Khan *et al.* 1961).

This research was planned not only to conduct an experiment with bullocks, but also to investigate the causes of the slow acceptance of molasses as a feed in the villages. It is concluded that the lack of suitable distribution, advertizing and retailing is the cause. Village people showed considerable interest in the feeding of molasses. However, this research did not lead to any plan of retailing the molasses in the area. Village leaders who took interest to inquire at the Mill were put off, instructed to return at a later time and told that they could not purchase less than 100 maunds at one time. Some village men, influenced by the campaign, still ask the authors, months later, if some way cannot be devised to supply them with molasses. The fact that this compaign did not lead to distribution of the molasses in the villages was neither the fault of those who conducted this phase of the investigations nor of the villages. It is not the "backwardness of live-stock owners" that prevents the marketing of molasses by the sugar mills in the small towns and villages of West Pakistan. If suitable distribution centres were established, advertizing and modern merchandizing methods followed, and retail outlets arranged, a large part of the molasses from any one sugar mill could be sold in the nearby areas from which it obtains most of its sugar cane. The molasses could be delivered back to the villages by the same vehicles as now return empty for hauling the cane.

It is recognized that molasses may be sold mixed into a formula mixed feed, but it may also be sold in liquid form if it can be handled in this way. Cheap plastic containers made in Pakistan can be used to transport molasses to the village. Anticipating difficulty in the transportation of molasses at the local village level, research was done on the use of polyethylene plastic (available in Pakistan) inner liners for gunny bags or bullock carts. This is a very economical material; for instance a plastic liner for a gunny bag will cost less than the burlap covering. Tests revealed that such containers would withstand as much handling abuse as other types of containers which coolies normally handle (such as oil tins, cement bags, etc.). It was believed that village people can provide their own molasses containers to carry molasses to their homes from a village distribution or sales point.

The same persons who deliver sugar cane to the mill can haul molasses home in the same vehicles as they brought the sugar cane—as they do ammonium sulphate fertilizer now. This means if they purchase either liquid molasses or a mixed feed containing molasses, there would be no problem of payment, if credit were given, because the amount could be deducted from payment for the sugar cane. In discussions, village leaders made the point that they would likely buy liquid molasses at times when they would not buy mixed formula feed. They could always mix molasses with the feed which they already had in their home villages. The liquid molasses could be taken by them and mixed with whatever oil cakes, bran or roughages they might have in the villages. By adding molasses, any village or individual may extend the local oil cakes by one-third, increasing the available feed supply by that amount.

Aside from feeding livestock, molasses is used for distilling alcohol, moulds for casting in foundries, and for tobacco. Also, some of the molasses in Pakistan has been exported to other countries, where it is fed to livestock. However, thousands of tons of molasses have gone to waste in Pakistan. The Sugar Commission of Pakistan has recommended that sugar mills manufacture power alcohol from molasses (Pakistan Times, 1960). However, sugar mills often must transfer the molasses to their alcohol distilling units at a book value of Rs. 0.50 or less per maund of 82 pounds so as not to show a loss on the distilling process. Molasses may be assumed to have a feed value for livestock of 60 per cent to 100 per cent of that of cereal grains. Thus, if an average price of Rs. 12.00 is taken for cereal grains, the feeding value of molasses for feeding livestock should be assumed at not less than Rs. 7.00 per maund. This would give adequate margin to sell molasses for much less than its true feeding value and provide for advertizing, distributing, and retailing molasses in thousands of villages.

**Summary and Conclusions:**

A $2 \times 2$ factorial experiment was conducted fattening 12 old bullocks to compare various percentages of rice straw and bagasse pulp, molasses, rice bran and cotton seed cake and rapeseed (*toria*) oil cake. There are no statistically significant differences among the rations. More favourable responses in one group are largely due to differences in individuality in the animals. Bagasse pulp proved to be a fair roughage at a 10 per cent level of the ration. The fattening of old bullocks is feasible and economical under rural conditions. Molasses can be used as a substitute for grains at 20 to 25 per cent of the ration. The cost of production can be reduced by the utilization of industrial byproducts such as molasses and bagasse.

The survey and demonstration in the villages conducted as part of this research program give assurance that village livestock owners would feed molasses to their animals if efforts were made to "sell" them on the idea and make molasses available to them at a reasonable price.

**Acknowledgements :**

The authors are grateful to Mr. W. U. Khan, General Manager, Gujranwala Sugar Mills, Rahwali, who took great interest in the experiment. Also, the Mill helped to finance this experiment on a 50 : 50 basis and supplied the molasses free of cost for this trial. The whole hearted cooperation of the Mill Staff is also acknowledged. Our thanks are due to Mr. Oscar Sellers, Agricultural Extension Advisor, US AID, who helped in organizing and conducting the molasses campaign in the villages of the area. To Mr. Ishaq Shah, Livestock Economist, goes the credit for making the preliminary survey of the feeding practices in the area surrounding Rahwali. We are grateful to Mr. William S. Hedrick, of the Engineering Development Activity, Lahore Church Council, for the research on polyethylene plastic bags. Our special thanks are due to Mr. Saleem Qureshi, Assistant Research Officer, Animal Nutrition Section, College of Animal Husbandry, Lahore, who performed the statistical analysis.

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# Bagasse Disease of the Lungs[1]

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BAGASSE is the name given to sugar cane after it has been crushed and the juice has been extracted. The term was originally used in Provence, France, to refer to the refuse from the olive-oil mills. Bagasse disease of the lungs, or bagassosis, is a pulmonary disorder brought about by the inhalation of dried bagasse dust. It is a rare disease, with only some 30 to 40 cases reported in the medical literature, having been first described in 1941 by Jamison and Hopkins (8), of New Orleans.

So far as is known today, the disease occurs only in people who have been exposed to the inhalation of dried bagasse dust. Industrial engineers have been aware that exposure to the dust was an industrial hazard, but very few physicians are cognizant of this fact. The fibers of bagasse are tough and possess insulating properties, which explains its use in the manufacture of acoustical and thermal insulating building boards and materials. More recently it has been used in the production of refractory brick.

Two factors are largely responsible for the lack of widespread information about bagassosis. In the first place, most of the reported cases occurred in men who handled bagasse derived from sugar cane grown in Louisiana, and the disease has been localized to certain communities. In the second place, men handling or cutting the finished products have not developed the disease because the heat and manufacturing processes destroy the fungi and bacteria as well as possible allergic protein, and the dust hazard in the modern fac-

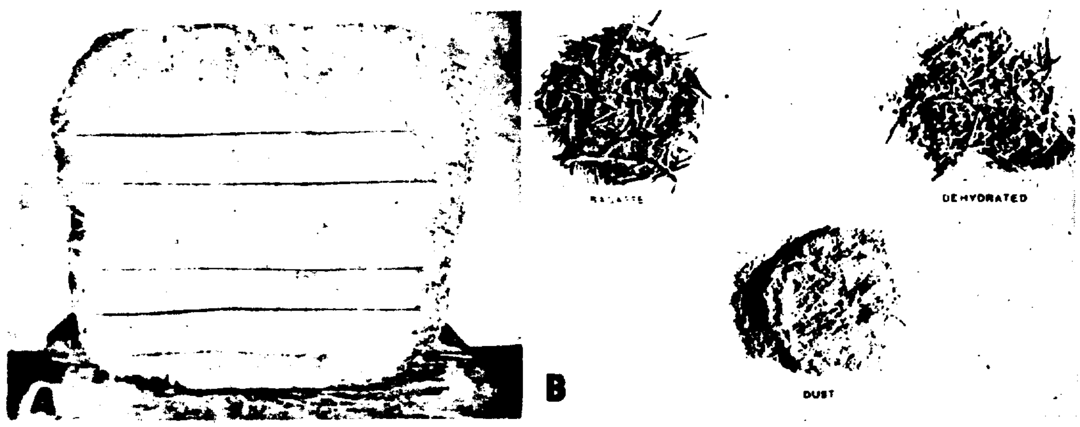


**Fig. 1.** A. The bagasse is shipped from Louisiana in tightly compressed bales. The first stage in processing it consists of breaking up the bales and grinding up the bagasse into small fibers or fine powder. This process is extremely dusty and is a serious industrial hazard unless special precautions against the dust are taken or the bales are broken up under water.

The photograph is of a bale of "dehydrated" bagasse, which is much less dusty and which is said to be less hazardous in handling.

B. Three different forms of bagasse: 1. Bagasse as it appears when broken free from the bale. Notice that it is a mixture of large fibers and very fine dust particles. 2. A collection of bagasse dust which was removed from the rafters and beams in the grinding room. This dust is a very light fine brown powder. 3. Dehydrated bagasse has most of the fine particles of dust and dirt removed, leaving chiefly the larger fragments of cane.

[1] From the Mallinckrodt Institute of Radiology, Washington University School of Medicine, Saint Louis, Mo., and the Department of Radiology, Missouri University School of Medicine, Columbia, Mo. ...



Radiology 49:556-567. 1947

TABLE I: COMPOSITION OF TISSUES OF SUGAR CANE*

| Constituent | Pith, % | Bundles, % | Rind % |
|---|---|---|---|
| Ash | 1.68 | 3.58 | 1.64 |
| Fat and wax | 0.41 | 0.72 | 0.98 |
| Protein | 1.94 | 2.00 | 2.19 |
| Pentosans | 32.04 | 28.67 | 26.93 |
| Cellulose | 49.00 | 50.00 | 51.09 |
| Lignin | 14.93 | 15.03 | 17.17 |

* From Browne, C. A.: Chemical Composition of Bagasse Dust. J. Am. Chem. Soc. **26:** 1221–1235, 1904.

tories has been largely eliminated. These conditions have restricted bagassosis to the communities which grow sugar cane and process it into sugar, such as Louisiana, or to the cities where the bagasse is manufactured into building board, as in England, or where it is used in making refractory brick, as in Missouri. Bagassosis also occurs in men employed in the Cuban sugar industry, where much dust is produced in handling sugar cane at the time it is cut. According to Manas (10) the Cuban disease is identical with that induced by the bagasse dust derived from Louisiana cane. In the Hawaiian Islands, bagasse is used for fuel, in a safe manner apparently, for we were unable to find reports of cases observed there.

Bagasse dust (Fig. 1) consists for the most part of pith particles with some bundle and rind fibers. The chemical analysis of samples of bagasse varies slightly depending upon the virility and agronomic factors, such as the soil, fertilizer, etc. Hunter and Perry (6) state that bagasse yields from 3 to 4 per cent ash and that 50 per cent of the ash is amorphous silica. Also that microscopic and x-ray diffraction analysis of the ash yields 3 to 4 per cent silica. This is an insignificant amount, and even if the ash were 100 per cent silica, it would still be regarded as a nuisance dust. Hence, it is improbable that the minute quantity of silica is an etiologic factor in the development of bagassosis.

Table I gives the approximate chemical composition of the tissues of Louisiana purple cane on the basis of the percentage of dry matter; Table II gives the approximate chemical composition of bagasse obtained from Louisiana purple cane.

### SYMPTOMS AND CLINICAL COURSE

The symptoms and clinical course of bagassosis are variable and depend largely on the length of exposure and the density of the inhaled bagasse dust. A bacterial and mycotic examination of bagasse is difficult because it is a complex organic substance and has mixed with it dirt and fertilizer, is invaded by bacteria, and is subjected to fermentation processes while the sugar cane is lying in the open field. At present, Dr. Morris Moore is undertaking these studies and has cultured several different kinds of fungi, as well as different bacteria, but his results are not yet available. To give a little idea of this problem, Hunter and Perry (6) estimated that 1 gm. of the air-borne bagasse dust contained 240,000,000 fungal spores, and they isolated some twenty different species by culture methods.

TABLE II: COMPOSITION OF CANE FIBER (BAGASSE)*

| | |
|---|---|
| Cellulose | 55% |
| Xylan | 20% |
| Araban | 4% |
| Lignin | 15% |
| Acetic Acid | 6% |

* From Browne, C. A.: Chemical Composition of Bagasse Dust. J. Am. Chem. Soc. **26:** 1221–1235, 1904.

A review of the various case reports brings out certain characteristic features. In general, about two months of exposure to the dust are required before symptoms appear, although the time has varied from three weeks to two years (14). The disease manifests itself as an acute febrile illness with extreme shortness of breath, a persistent cough with scanty mucoid sputum, and a profound weakness. The onset is insidious and gradual, for these patients usually do not realize that they are ill until they are seized by a sudden coughing spell and become so dyspneic as to force them to rest. The dyspnea is extreme. The patient described in Case I required oxygen for nearly two months. He was also cyanotic, but as a rule cyanosis appears in only the most severe cases. The usual appearance is that of a patient with a severe bronchiolitis and pneumonia.

Patients with long exposures to heavy concentrations of the dust are critically ill. Among the 24 cases collected by Hunter and Perry (6) there were 2 deaths, a mortality rate of 8.3 per cent, which is sufficiently high to indicate that this is an industrial disease of a serious nature. On the other hand, most of the patients with only moderate or short exposure to the dust in light concentrations contract a less severe form of the disease, which usually clears up in two to six months.

PHYSICAL FINDINGS AND LABORATORY EXAMINATIONS

At the onset the fever may range from 37° to 39° or 40° C. and persist for as long as two to three months before gradually subsiding. The pulse rate is correspondingly elevated. The respiratory rate is increased, ranging from 20 to 40. The supraclavicular and infraclavicular areas on the anterior chest wall may be retracted on inspiration. Percussion of the chest reveals a slight decrease in resonance. The breath sounds are not decreased, while the whispered voice may be increased, depending on whether or not areas of confluent consolidation have developed in the lungs. More important are the moist crepitant râles that are heard throughout both lungs. The cardiovascular system is unaffected. The mucosa of the nasopharynx is not injected. There is no enlargement of the lymph nodes, and the liver and spleen are within normal limits.

During the acute phase of the disease in severe cases, the white blood count may reach 16,000 to 20,000; in the moderately severe cases it may run around 10,000 to 12,000. As the pulmonary process clears, the number of white cells gradually declines and returns to normal. In the differential count there is a definite shift to the left, with the polymorphonuclear cells forming 70 to 90 per cent of the total. Of special note is the fact that an eosinophilia is usually present. The average eosinophil count in the 11 cases reported by Sodeman and Pullen (14) was 3.5 per cent. In our Case I the eosinophils ranged from 4 to 8 per cent. The red blood cells and hemoglobin are not affected. The blood chemistry determinations are within normal limits. Agglutination tests for coccidioidomycosis, typhoid, etc., were all negative in our patients. Repeated attempts at culturing the sputum for fungi were also negative, as has been the experience of most other observers. Microscopic examination of the sputum did not reveal any abnormal cells or recognizable fungi or spores, but small highly refractile bodies were repeatedly seen in the sputum, and these may have been fragments of bagasse.

Examination of sputum concentrates has never revealed acid-fast bacilli. Injections of the sputum into guinea-pigs failed to produce evidence of tuberculosis. Urinalyses were always negative. The sedimentation rate was definitely elevated in Case II, a finding which has been reported by others.

RADIOGRAPHIC APPEARANCE

Radiographic findings in bagasse disease of the lungs are largely dependent on the duration of exposure to and the concentration of the bagasse dust. In patients who receive a prolonged exposure to heavy concentrations of the dust an extensive fine punctate infiltration develops throughout both lungs. In our series the most extensive pulmonary infiltration occurred in Case II. The punctate type of infiltration tends toward a nodular appearance as the disease begins to clear up. In the beginning, the infiltration is so dense that areas of consolidation develop, usually about the hilum and/or in the adjacent portions of the lungs. The infiltration pattern is not sufficiently characteristic to enable one to make a diagnosis of bagassosis by merely examining the film. In this disease one must follow the old dictum: "There can be no radiographic diagnosis of bagasse disease of the lungs without a history of exposure to bagasse dust."

The one remarkable radiographic feature of this disease is that the process of pulmonary infiltration, as observed on the roentgenogram, is a reversible one. This characteristic distinguishes bagassosis from the other pneumoconioses, in which a permanent fibrosis of the lung develops. Approximately two months are required from the time that the disease is at its height and exhibits the largest amount of infiltration in the lungs before appreciable resolution can be detected on the roentgenogram. By three months only minimal changes remain, and in five to six months the lung fields appear normal roentgenographically. This period of resolution can be well visualized by following the serial roentgenograms in Cases I and II, as reproduced in Figures 3 and 4, respectively.

Patients receiving short or intermittent exposure to bagasse dust in lighter concentrations may develop only a fine granular type of bronchial infiltration throughout both lungs, slightly heavier in the areas immediately about the hilum or, as in Case III (Fig. 5), in the lower and medial portions of the left lung. On close examination, this type of infiltration bears a close resemblance to the fine lacy network that is sometimes formed by residual lipiodol in the alveoli. This is in conformity with the pathologic reports of the lung biopsies (Fig. 2), which demonstrate cellular debris in the alveoli and in the bronchioles, and agrees to some extent with the clinical impression that these patients have an acute bronchiolitis and pneumonia. This patient (Case III) received an intermittent exposure to bagasse dust for over a year, but on removal from contact with the dust, his pulmonary symptoms disappeared and we presume that the findings in the roentgenogram did likewise, although a follow-up film was not made until a year later. At that time, the lung fields appeared to be within normal limits.


Fig. 2. Photomicrographs of biopsy specimens of the lung obtained by aspiration through a large needle in the sixth and seventh week. These are the only pathological sections available for the study of the pulmonary changes in bagasse disease. They are reproduced from Sodeman and Pullen (14), who describe a fibroblastic reaction of the interstitial tissue with small needle-like spicules of an irregular foreign material imbedded in the pulmonary tissues. The spicules are not numerous. Under the polarizing microscope these spicules rotated the plane of light and they appeared similar to particles of bagasse. These authors point out that the alveolar cells are numerous, very large, and possess a "foamy" cytoplasm and in some areas fill the alveolar spaces.

PATHOLOGY AND ETIOLOGIC FACTORS

Material for pathologic examination is limited, as only two deaths from bagassosis have been reported. Sodeman and Pullen (14) were fortunate enough to obtain sections from the lung of one patient at autopsy and from another by lung biopsy obtained with a 20-gauge needle. Photomicrographs of the biopsy specimens are shown in Figure 2. They are described by these authors as showing a fibroblastic reaction of the interstitial tissue with small needle-like spicules of an irregular foreign material imbedded in the pulmonary tissue. The spicules were not numerous and averaged 2 - 8 microns. When examined under the polarizing microscope, they rotated the plane of the polarized light and, microscopically, appeared similar to particles of bagasse. The alveolar cells were more numerous, were very large, possessed a "foamy" cytoplasm, and in some areas filled the alveolar spaces. The authors summarized these observations by saying that the pulmonary changes appeared to represent an organic pneumoconiosis.

The exact etiology of bagasse disease is obscure, but one fact is certain; namely, that exposure to dried bagasse dust can initiate a pathologic process in the lungs. The mechanism by which these changes take place and the reaction induced by the bagasse remain unsolved. To date, the disease has not been reproduced in experimental animals. We have made several attempts to do this and are now constructing additional equipment with which we hope to be more successful.

In their study of this disease, Jamison and Hopkins (8) were able to grow a fungus from two sputum cultures on one patient, but they did not describe its type or characteristics. Castleden and Hamilton-Paterson (1), as well as Gillison and Taylor (4), failed to isolate a fungus from the sputum of their patients. Others and ourselves have cultured various fungi from the sputum but have considered them to be contaminants or not associated with the disease.

A pulmonary disease known as maple bark disease is caused by the inhalation of fungi which grow on dead maple trees that have been cut for over a year. The patients are dyspneic, lose weight, have a productive cough with varying amounts of sputum, and fever ranging to 103° F., with night sweats and substernal pain. The clinical picture and chest roentgenograms closely resemble those of bagassosis, but all efforts to identify a similar spore in bagasse dust have failed to date. In the opinion of Towey, Sweany *et al.* (15) the reaction to the spores was due to a local toxic effect and foreign body reaction combined with a delayed effect resembling protein sensitization in certain clinical and immunological aspects. Fawcitt (2) gives a long list of pulmonary mycotic infections that appear in agricultural workers, such as hay workers, grain workers, stablemen, cattlemen, etc. Thus, the possibility that bagasse disease may be due to a fungus has some precedent in other diseases, but there is no clear evidence to support this idea at the present time.

Another possibility is that a bacterium in the bagasse dust may be the inciting factor, similar to that which appeared in the stained cotton of the 1940 crop that was used in the English upholstering and mattress plants where the workers were exposed to high dust concentrations from the cotton. Schneiter *et al.* (12) examined samples of the cotton and found a gram-negative bacterium which was the etiologic factor. This disease, however, required an exposure to the dust of only one to six hours and was characterized by a sudden onset with an acute phase lasting twenty-four hours, irritation of the nasopharynx, cough, chills and fever, with all the symptoms disappearing in a few days. In this way it is quite distinct from bagassosis, in which no specific bacterium has yet been isolated. It was further suggested that an endotoxic-like substance might be produced by the bacterium, and, that this, when inhaled, was the etiologic factor.

The first investigators to suspect an allergic reaction as the cause of bagassosis were Castleden and Hamilton-Paterson (1). They prepared four types of extracts from bagasse for intracutaneous injection. Three patients gave positive reactions, and a group of controls who did not have bagasse disease gave negative results with the saline extract. It was concluded that the acute phase of bagassosis is possibly an allergic response in the lungs to this antigen with, but more probably without, an infective element; also that the pathological process could be: (*a*) a form of silicosis which supervenes upon the allergic phase during or after the resolution of the latter; (*b*) a response on the part of the lung to the crystalline cellulose in the bagasse; (*c*) a chronic process of fibrotic nature occurring in tissues which have become edematous from their allergic response to the antigen.

Sodeman and Pullen (13) repeated the tests conducted by Castleden and Hamilton-Paterson, using extracts made from bagasse according to their directions. Ingestion of these extracts produced similar reactions in all patients and controls, and the investigators concluded that the reactions were an irritative phenomenon due to the release of histamine and did not necessarily indicate a sensitization to bagasse.

Allergic pulmonary disease is well known, such as the syndrome described by Löffler (9), the symptoms of which resemble those of bagassosis and include cough, fever, leukocytosis, eosinophilia, and an elevated sedimentation rate, while the chest radiographs reveal transient areas of consolidation that appear and disappear rapidly. Furthermore, these patients have attacks of asthma, only a few râles are present in the lungs, and the disease clears up in about a week.

From these studies, the possibility that bagasse disease may be an allergic pulmonary reaction *per se* or a contributing factor cannot be ruled out, but evidence in favor of this view is not very strong.

Tuberculosis does not need to be considered as an etiologic factor in the absence of tubercle bacilli and negative tuberculin tests.

In summarizing the etiologic factors of bagassosis, one must conclude that it is an acute bronchiolitis and pneumonia due to bagasse dust. Whether or not the pathologic reaction is due to fungi, bacteria, or a virus associated with the dust, or to an allergic response to the bagasse or its possible infectious agents or their products, or to some chemical or physical property of the dust, or any combination of the above, has not been determined and is still open for investigation.

## TREATMENT

In view of the obscurity of the exact etiology of bagassosis, there is no specific treatment. Most of the patients have been treated symptomatically. There was no notable response among those in whom the "sulfa" drugs were tried or in the one case treated by penicillin. Oxygen has afforded some relief of the dyspnea in the more serious cases.

## CASE REPORTS

CASE I (Fig. 3): R. R. H., a 27-year-old white, married, firebrick worker, was transferred to this hospital by ambulance on May 18, 1946. From 1942 until August 1945, the patient was in the Army. He had been overseas and had served in North Africa, Sicily, and Italy. He was returned to this country in 1945 and was discharged in August in good health.

In January of 1946 he started working for a firebrick company. His work consisted of breaking up bales of bagasse that had been shipped from Louisiana and shoveling it into a "shredder," a machine that breaks up the larger bundles of bagasse and grinds it into a fine powder. This operation was conducted in a room with one side open to the outside, but it was extremely dusty even when the bagasse was dampened with water or mixed with wet sawdust. The patient usually wore a mask which covered his nose and mouth, but at times he removed the mask and received numerous exposures to the dust without any protection.

About the first of April, after three and a half months of exposure, a dry, hacking cough developed and by the middle of April the patient was dyspneic on even mild exertion. At that time he experienced two chills on successive nights, and on coughing he brought up small to moderate amounts of foul, black, watery sputum which, he said, contained black specks of bagasse. The sputum continued to be of this type for only a few days and then became mucopurulent, containing a few specks of blood; it amounted to approximately one-third of a cup per day. At the same time the patient became very weak and could hardly get out of bed. Fever began at the time of the chills and persisted throughout the course of the illness.

On April 19, the patient entered a local hospital and an x-ray examination was made of his chest, revealing an extensive bilateral infiltration of both lungs, which was described as a "snow storm." He remained in the hospital about one month, during which time he received penicillin and oxygen, but he continued to become weaker. The chills and fever persisted and he had profuse night sweats. His weight decreased from 160 to 130 pounds. On May 18, 1946, he was transferred to this hospital for lergic phase during or after the resolution of the latter; (*b*) a response on the part of the lung to the crystalline cellulose in the bagasse; (*c*) a chronic process of fibrotic nature occurring in tissues which have become edematous from their allergic response to the antigen.

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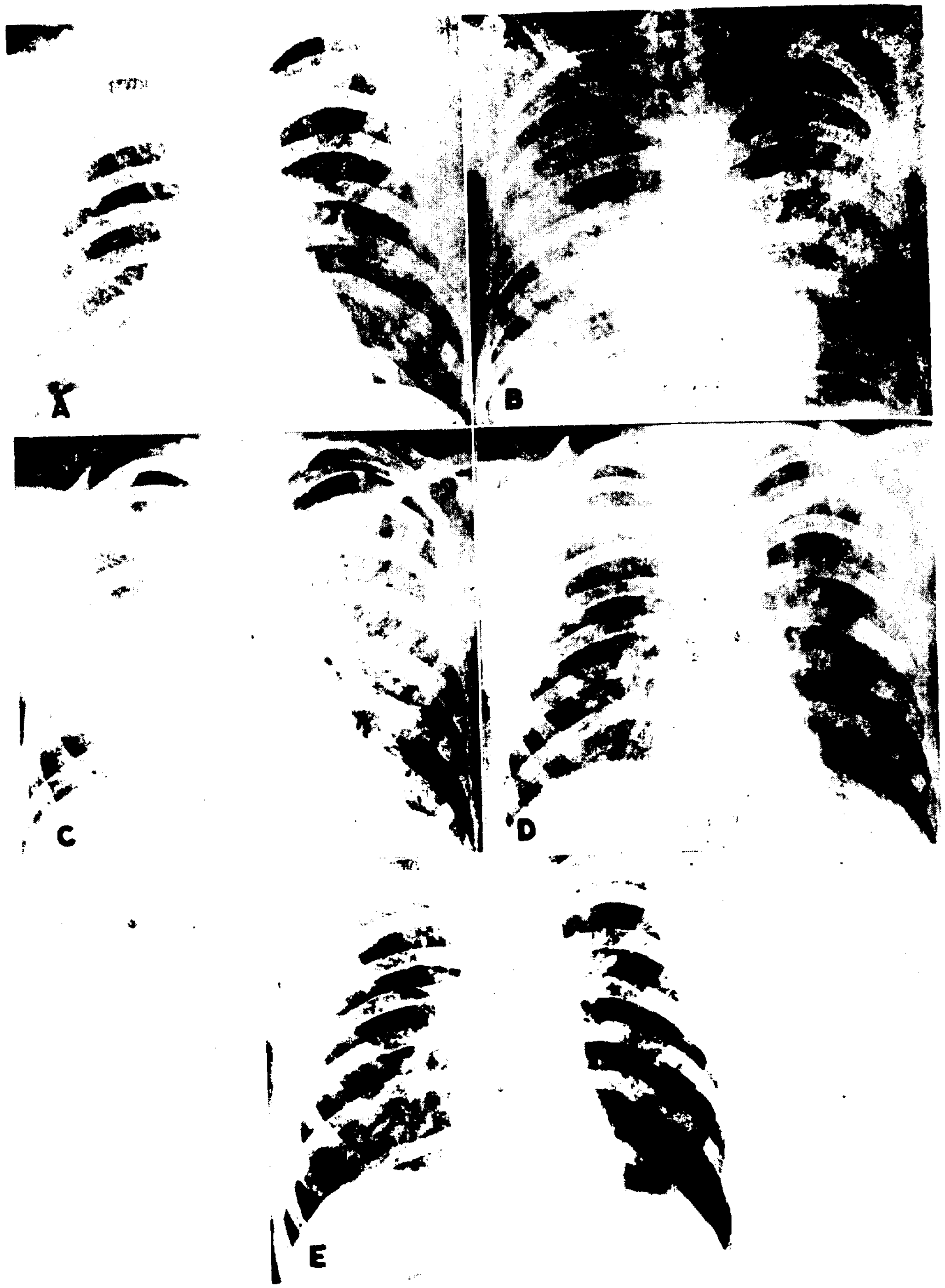


Fig. 3. Case I. Typical course of acute bagasse disease of the lungs, showing the changes that take place in the lung over a period of approximately six months.

A. The pre-employment film, which was considered to be normal.

B. Film made approximately one month after the patient became acutely ill following a period of three and a half months of exposure to bagasse dust. Note the symmetrical distribution of the small punctate areas of pulmonary consolidation and the peribronchial thickening in both lungs. The greatest change is about the hila and in the middle thirds of both lungs. The initial film, made in April 1946, was not available for reproduction, but appeared approximately the same. The patient was extremely ill and required continuous oxygen therapy. [Legend continued on opposite page]

further study. On admission he had a temperature of 39.3° C., pulse 104, respirations 24, and blood pressure 110/78. He was dyspneic and orthopneic. He appeared acutely and chronically ill and was receiving continuous nasal oxygen. He did not complain of pain. He was not cyanotic.

Examination of the chest revealed marked retraction of the chest wall in the supraclavicular areas on inspiration. The percussion note was dull over the entire thorax. Tactile fremitus was unchanged. The breath sounds were loud, and many dry and coarse râles were heard in all areas. The whispered and spoken voice sounds were somewhat diminished. The heart was within normal limits. The rhythm was regular and the sounds were of good quality. The abdomen was slightly distended; the liver was slightly enlarged; the edge of the spleen could be felt. No other findings were obtained on physical examination.

The reports of the blood studies were as follows: red blood cells 5,000,000; white cells 18,150; hemoglobin 13.5 gm.; differential count, basophils 5, eosinophils 8, juveniles 3, stabs 7, segmented polymorphonuclears 67, lymphocytes 11. The sputum was white, frothy, and mucoid. On microscopic examination it was reported that several refractile bodies were seen, but no one was able to identify them. Repeated examinations of concentrated sputum specimens were all negative for acid-fast bacilli. Repeated cultures of the sputum were negative for fungi and contained only those organisms that are usually present. Urinalyses were all within normal limits. The blood Kahn reaction was negative. A culture of the blood failed to grow any organisms. Blood chemistry analysis, including the icterus index, was within normal limits.

Skin tests were made with 1,000-unit extracts of several molds, including aspergillus, which gave immediate negative reactions. A skin test for coccidioidomycosis with 0.1 c.c. of 1:1000 dilution was negative at both twenty-four and forty-eight hours. The electrocardiogram was within normal limits.

By the first of June the patient began to feel better. His temperature dropped to normal. The respiratory rate decreased. A chest film made at this time revealed the same type of miliary infiltration throughout both lungs, but to a less extent than the original film made at the time of his admission to the first hospital in April. It was necessary to keep him supported with oxygen, as otherwise he became very dyspneic and was troubled by a constant cough. His extreme weakness persisted. He was treated symptomatically, and penicillin was continued empirically through June 6, but it is doubtful if it was effective in the treatment. It was used because the patient was seriously ill and his clinical picture suggested a pneumonia or pulmonary infection. The white blood count had now dropped to about 13,000.

By July 5 the patient was able to get along without oxygen and to be up in a wheel chair. Only a few râles persisted throughout the lungs. He was coughing less and was gaining back his strength. The vital capacity was determined at this time and amounted to 1.8 liters, which was about 42 per cent of normal. This increased to 2.0 liters by July 11, at which time the patient was discharged. He returned to his home and continued to gain strength. The non-productive cough persisted, and on Oct. 7, without any apparent reason, he coughed up about a cupful of bright red blood. He was sent back to the hospital on Oct. 27 for a bronchoscopic examination. This was done by Dr. A. C. Stutsman, who was unable to find any bleeding point or source of the hemorrhage. He mentioned that the bronchi appeared to be thickened and grayish in color, with slight injection of the mucosa. A small amount of seromucoid secretion was present in the main bronchi. The vital capacity was retested and had now increased to 3 liters. The venous pressure was 108 mm. of saline. The circulation time (arm to tongue) was 15 seconds with decholin.

CASE II (Fig. 4): E. L., a 42-year-old married colored laborer, had worked for the same brick company as the man reported in Case I. His family history and past history are irrelevant. From August 1943 to Feb. 29, 1944, he worked in the dry press department where he was subjected to light exposure to silicate dust with very minimal free silica. He was discharged because of absenteeism. On April 4, 1944, he was rehired and worked in the insulation department, where he was exposed to ground dry bagasse dust until June 29, 1944, an exposure of eleven weeks. He had no previous history of any respiratory condition or pleurisy and had never been sick before this present illness.

In the middle of May 1944, this man experienced an acute coughing and choking spell in the company cafeteria. He also noticed that he was somewhat

C. The heavy areas of consolidation have undergone partial resolution. Note the fine granular shadows that correspond to consolidation in the air sacs of the lungs. The patient was now feeling better, but it was necessary to keep him supported with oxygen.

D. This film was made two weeks after discharge from the hospital and shows practically complete resolution of the miliary consolidation in both lungs. The patient was now able to be up and about but was still weak and coughing.

E. On Oct. 7, this patient coughed up a cupful of bright red blood. A bronchoscopic examination failed to reveal the bleeding point or source of the hemorrhage. The bronchial mucosa appeared to be normal and free of any excessive secretion. The vital capacity had increased to 3 liters, venous pressure was 108 mm. of saline, and the circulation time was 15 seconds with decholin. The patient had gained weight and within a few months was doing light work.


Fig. 1. Case II. Typical pulmonary changes in bagasse disease of the lungs with ultimate resolution.

A. The patient had been ill for two months prior to taking of this film. Note the bilateral involvement of the lungs greatest about the hili. Areas of consolidation are present in the adjacent areas of the lung. The characteristic features are the small patchy areas of consolidation in the smaller divisions of the lobules.

B. Definite resolution began to take place within the next two weeks, although the patient only brought up small amounts of clear, mucoid material. He was now beginning to feel better but was still quite ill.

[Legend continued on opposite page.]

...t of breath on exertion and realized that i was ...e difficult for him to do the manual labor that ... required in his job. Shortly thereafter, he con...ed a private physician, who had x-ray films made ...he chest. These revealed an extensive miliary ... of infiltration throughout both lungs, with areas ...onglomeration and consolidation immediately ...ut the hila. Fever was noted at this time.

...n July 24, 1944, the patient was admitted to a ...itarium. Upon admission it was reported that ...was dyspneic, with a temperature of 99.2° F., ...e 116, and respirations 28. He had lost about ... pounds in weight. It is interesting that he ...ught his illness had developed gradually over a ...iod of several months. He had repeated night ...ats. He described the onset as characterized ... cough, pain in the chest, and the spitting up of ...me blood, accompanied by chills and fever, with shortness of breath and a gradually increasing weakness.

On physical examination the patient appeared to be in a fair state of nutrition. The heart was within normal limits, but the rhythm was irregular. Blood pressure was 120/94. Many fine crepitant râles were heard over both lungs. The breath sounds were increased, as was the whispered voice.

Repeated sputum examinations were negative for acid-fast bacilli. The blood Kahn reaction was negative. Guinea-pigs were inoculated with the sputum on Aug. 10, 1944, and again on Oct. 21, 1944. Both animals were sacrificed, autopsied, and were negative for tuberculosis. The sputum was also cultured and was negative for fungi. On July 29, 1944, the vital capacity had fallen to 2.35 liters. The sedimentation rate was 22. Urinalysis was within normal limits.

From the time of his admission to the hospital until the middle of August, the patient had a fever ranging from 98° to 101° F. He was treated symptomatically and on about the same regime as patients with tuberculosis in the sanitarium. He gradually improved, the sputum became scant, and there was a gain in strength and weight. On Feb. 4, 1945, approximately seven months later, he was able to be discharged. The infiltration in the lungs, as demonstrated in the chest films, gradually cleared.

On May 25, 1945, the patient returned for a checkup. At that time he had no sputum, no cough, no chills, and no fever. He had nearly regained his strength. He had done no work since leaving the hospital and had been convalescing at home. Chest films at this time revealed only coarse markings, with little residue of the initial infection.

CASE III (Fig. 5): O. G., a 30-year-old white married laborer presents an interesting case, as he had only moderate pulmonary involvement as demonstrated roentgenographically. He gave a history of the usual childhood infections, as well as pneumonia. In 1941 he had a duodenal ulcer which continued to cause him trouble intermittently to the time of admission. During the x-ray examination of the gastro-intestinal tract the chest was observed fluoroscopically and was reported as negative. Early in 1944 he contracted undulant fever from which he recovered uneventfully.

Prior to his employment at the brick company, the patient worked for a year and a half in a coal mine. From 1939 to 1943 he was employed by a firebrick company in a position where he was exposed to moderate dust concentration of silicates. Late in 1943 he was transferred to another department, where he received intermittent exposure to a fairly heavy concentration of bagasse dust for about one year. At the end of that time, late 1944, he suffered from a cough which was non-productive, complained of slight substernal pain, was dyspneic on exertion, and felt weak. He continued to work, and his record shows that throughout his entire period of employment he never lost a day from sickness. He consulted a physician on Sept. 18, 1944, at which time a chest film was made. This physician reported exaggeration of the hilar markings, with a diffuse pulmonary fibrosis and a disseminated pulmonary infiltration throughout both lungs of an unusual type. The physician requested a more complete history with reference to dust and respiratory hazards. The patient was then transferred from the plant and given a position as a clerk, where he no longer was exposed to dust. His symptoms continued, and on Oct. 19, 1944, stereoscopic films were made of the chest and were interpreted as demonstrating a pneumoconiosis.

The symptoms gradually disappeared and the patient's strength increased. Another chest film was made on Sept. 22, 1945, when the radiologist reported that the punctate infiltration in the lung fields was much less evident and that the pulmonary infiltration was of a reversible type, and again requested that a detailed study be made of the dust exposure to which this man had been subjected.

The subsequent review of the dates of this patient's exposure to the silicate dust and later to bagasse dust, with the development of his pulmonary illness and the reversible changes in the lungs, as demonstrated on the roentgenograms, was the first suggestion that this was a case of bagasse disease of

C. Small areas of pulmonary infiltration and peribronchial thickening remain in both lungs despite marked improvement. Cough was now non-productive and there was no fever or any other symptom.

D. Approximately eight months after the development of the disease, the lung markings are still coarse. The patient still complained of weakness and shortness of breath but was able to be up and around.

E and F. About one year after development of the disease the lungs have regained their normal appearance. The patient felt well and was able to go about his routine duties.

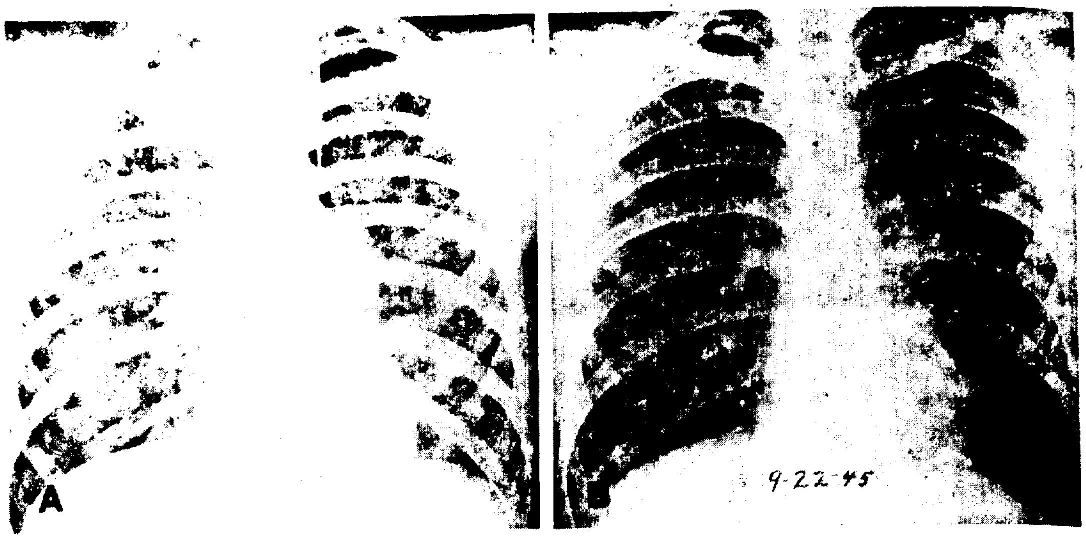


Fig. 5. Case III. Typical case of mild bagasse disease of the lung induced by intermittent exposure to a light concentration of bagasse dust over a period of one year.

A. After nearly a year of intermittent and light exposure to bagasse dust, this patient began to complain of a non-productive cough, with weakness, slight substernal pain, and shortness of breath on exertion. He continued to work and throughout his entire period of employment never lost a day from sickness. This film was originally reported as showing exaggeration of hilar markings, with a diffuse pulmonary fibrosis and a disseminated pulmonary infiltration of both lungs of an unusual type. The physician (D. L.) requested a full history with reference to dust exposure and respiratory hazards. The man was then transferred to a department free of bagasse dust.

B. Approximately one year later, this man was re-examined because of the findings noted above. The radiologist now reported that the punctate infiltration in the lung fields was much less evident and that the pulmonary infiltration was of the reversible type and, consequently, was something unusual and not a typical pneumoconiosis. This observation was the stimulus for an intensive check-up on the patient's exposure to various dusts and led to the incrimination of bagasse dust.

the lungs. This was the first patient that had been recognized as having the disease in this community and focused our attention on this industrial hazard. Today this patient is well and symptom-free. His chest film is well within normal limits.

## CONCLUSIONS

1. Inhalation of bagasse dust, derived from sugar cane after it has been crushed and the juice extracted, incites a pathologic process in the lungs which has been termed "bagasse disease of the lungs," or "bagassosis."

2. Information concerning bagassosis should be disseminated because bagasse is being used more extensively in the manufacture of thermal and noise-insulating building materials and in the manufacture of refractory brick. As such, it constitutes a serious industrial hazard unless properly handled.

3. Pulmonary changes incited by the inhalation of bagasse dust consist in a diffuse infiltration and consolidation, an acute bronchiolitis or pneumonia, that is similar to that seen in pneumoconiosis but in one respect is greatly different. It is a reversible reaction, with the process undergoing resolution and the lung regaining its normal appearance on the roentgenogram.

4. The exact etiologic factors in bagasse disease of the lung are as yet unknown, and this problem is still open for investigation.

5. Three cases of bagassosis are reported, including a discussion of the symptoms, physical findings, laboratory reports, and clinical course.

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## DISCUSSION

**Capt. A. Link Koven, U.S.P.H.S.:** As pointed out, the exact etiology of bagasse disease remains obscure. At least, we may conclude that bagasse may enter the alveoli and initiate a fibroblastic reaction and that by digestion and absorption, through the activity of cellular response, these changes are removed and a normal functioning lung (clear on x ray examination) remains. In view of the obscurity of the etiology of bagassosis and the lack of specific treatment, chief reliance at present is in the provision of a dust-free environment, introducing either proper exhaust ventilation and water spray or a change to a wet method of collecting and breaking the bales.

Because of the industrial importance of the properties of bagasse, its use will extend to other purposes. It can be anticipated that the incidence of bagasse disease of the lung will increase. The U. S. Public Health Service is interested in promoting practices that will prevent this disease and also in determining its exact etiology.

The small number of cases that have been recognized and described does not necessarily mean that the number of cases of this disease is limited. On the contrary, the comparatively recent recognition of this entity and the lack of its differentiation from several other similar diseases have minimized its real incidence and significance. It is of importance that the nature and diagnostic features of bagassosis be made widely known among industrial physicians and roentgenologists.

# NOTES SECTION

## Uses for Sugar Beet Pulp

Prospects are good for harvesting 25 million tons of sugar beets from one and one-half million acres in the United States in 1964. More than one million tons of dried beet pulp will be available for feed or industrial use. At present, pulp and molasses-pulp enjoy a ready and profitable market as animal feed, although this situation has not always prevailed and it could change at any time. Because a commodity should have several uses, it seems worthwhile to focus some attention on possible new industrial uses for this valuable beet by-product.

Four carbohydrates make up about 76% of the dry weight of beet pulp in essentially the following proportions: galactan, 6%; araban, 20%; cellulose, 25%; and pectin, 25%. Protein, ash, acetyl, and other constituents make up the remainder. Sugar beet gum (primarily galactan and araban) is water-soluble but difficult to extract from untreated pulp. Beet cellulose from cossettes is composed of relatively short fibers as compared with wood pulp cellulose. Pectin in beet pulp is water-insoluble, but can be extracted under mild acidic conditions. This pectin has poor gelation properties. Beet cellulose and gum are relatively inert chemically but pectin is not. Beet pectin contains acetyl esters, free and partially neutralized carboxyl groups, and a general structure that can be degraded under certain conditions.

Addition of lime to pulp results in several major changes which vary in character with the temperature of reaction. When lime is added to pulp at about 70°C, esters are hydrolyzed and the pectin molecule is degraded. Calcium ions react with the carboxyl groups of the degraded pectin molecules. The net effect is solubilization of the beet gum and destruction of the pulp structure.

Addition of lime to pulp at 35°C or below results in an almost instantaneous toughening of tissues because calcium ions react with free carboxyl groups to cross-link the pectin molecules into a three-dimensional lattice of giant colecules. Esters are hydrolyzed, but the rate of degradation of the pectin molecule is low. After the methyl esters have been substantially removed, the pectin chain is stable to hot and cold alkali because methyl ester groups are necessary for alkaline degradation of pectin.

J. Am. Soc. Sugar Beet Technol. 13(5):467-468. 1965

*Water soluble gum*

Hot lime solution converts beet pulp to a fluid mass which permits soluble gum to pass into solution. The solution can be carbonated and filtered, and the crude gum isolated by simple drying. Over 200,000 tons of crude gum is available from pulp, and an industrial use for it should be found. This process does not utilize the entire pulp; a residue of spent lime, cellulose, and degraded pectin remains as waste.

*Pressed Board*

Preliminary experiments have been conducted on the use of beet pulp and limed beet pulp as a structural constituent and bonding agent in pressed boards. Results are promising since the bonding action of pulp appears to be good. Much practical research must be conducted on the properties of boards made from beet pulp, particularly with respect to additives such as fiber and waterproofing agents, before the industrial potential can be evaluated.

*Thickening agent*

Untreated pulp contains pectin in an insoluble form that cannot be used as a gelation agent. Alkali-treated pulp, dried and finely powdered, may be mixed with sodium ethylene diamine tetraacetate, diammonium phosphate, and water to form a thixotropic gel having physical properties that may make it suitable for use in forest fire retardants. Tests of this processed pulp will be conducted in cooperation with agencies having this primary responsibility.

The possibility of manufacturing a valuable gum material from pulp is good. However, utilization of pulp directly as an ingredient for board manufacture or as an industrial thickening agent appears to be better. Further research to investigate industrial uses should prove rewarding.

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J. Dairy Sci.
45(7): 854-857, 1962


# RELATIVE MILK PRODUCTION VALUE OF BARLEY, DRIED BEET PULP, MOLASSES DRIED BEET PULP, AND CONCENTRATED STEFFEN FILTRATE DRIED BEET PULP [1]

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SUMMARY

Concentrated Steffen filtrate (CSF) is a by-product of beet sugar manufacture which may be added to beet pulp. A study was conducted to compare the feeding value of CSF dried beet pulp with plain and molasses dried beet pulp. Each of the three types of beet pulp was fully equal to barley in the replacement of approximately 25% of the energy of a basal ration consisting of 70% alfalfa hay and 30% barley.

Concentrated Steffen filtrate (CSF)[2] is a by-product of the Steffen process for the desugarization of beet molasses. It is a concentrated solution remaining after the removal of sucrose, and contains all of the other extractable solids of the sugar beet.

This material has been used for some time in a modified form (condensed beet solubles product) as a livestock feed. Washington workers (1) found beet pulp containing a combination of CSF and molasses to be equal to conventional molasses beet pulp as a part of the concentrate mix for milking cows.

Since considerable CSF is produced in beet growing areas, there was interest in studying further its nutritional value for the feeding of dairy cattle. Of particular interest was the value of dried beet pulp which contained approximately 28% CSF solids. In addition, it was desired to compare this material with plain and molasses dried beet pulp, and to evaluate all three beet pulp preparations with reference to barley.

## EXPERIMENTAL PROCEDURE

The study was made in two feeding trials, each with eight first-lactation, grade Holstein cows allotted to four treatments according to the extra-period, Latin-square, change-over design proposed by Lucas (8). The animals had all calved within a period of 25 days and were started on trial at an average of 62 days post-calving. The trials were of 175 days' duration with five 28-day periods, each preceded by a period of seven days to allow cows to adjust to changes in feeding regimes.

Prior to the trials the cows were all handled alike and fed alfalfa hay free-choice, with a high level of ground barley. A rationing plan was established for each cow for the entire trial on the basis of milk production predicted from a ten-day indexing period immediately preceding the initiation of the trials.

A basal ration consisting of 70% alfalfa hay and 30% barley was fed at full and at restricted levels of intake, which accounted for Treatments 1 and 2 in each of the feeding trials. The full-fed basal ration was estimated to meet the maintenance and production requirements of the cows and the restricted basal was fed to furnish 75% of the estimated net energy requirements. With this proportion of alfalfa hay in the ration, protein intake was adequate, even at the restricted level of intake.

The four test feeds were added in turn to the restricted basal ration in amounts estimated to support levels of production comparable to that on the full-fed basal ration. In Trial A, barley and dried beet pulp (BP) were added to the restricted basal in Treatments 3 and 4, respectively; and in Trial B, molasses dried beet pulp (MBP) and concentrated Steffen filtrate beet pulp (CSFBP) were involved.

The addition of the test feeds to the restricted basal resulted in rations which contained approximately 45% concentrates. In turn, the increments of test feeds accounted for about 45% of the concentrate portion and about 20% by weight of the total rations.

Received for publication April 9, 1962.

[1] Supported in part by Amalgamated Sugar Company, Ogden, Utah; Holly Sugar Corporation, Colorado Springs, Colorado; Spreckels Sugar Company, San Francisco, California; Utah-Idaho Sugar Company, Salt Lake City, Utah.

[2] Information on CSF furnished by S. L. Stovall, Spreckels Sugar Company.

TABLE 1

Composition of dry matter of feeds

| Feed | C.P. | E.E. | C.F. | NFE | Ash |
|---|---|---|---|---|---|
| | | | (%) | | |
| Alfalfa hay | 19.9 | 1.8 | 27.6 | 41.9 | 8.8 |
| Barley | 11.2 | 1.7 | 6.1 | 77.8 | 3.2 |
| D.B.P. | 7.9 | 0.4 | 22.9 | 65.2 | 3.6 |
| M.B.P. | 10.3 | 0.2 | 17.4 | 66.1 | 6.0 |
| C.S.F.B.P. | 14.7 | 0.4 | 17.7 | 54.4 | 12.8 |

The alfalfa hay was all from a single lot of one cutting from one field. The barley was all from one large procurement and averaged 47 lb per bushel, but varied from 40.7 to 50.1 lb among weights obtained at various times during the trials. The dried beet pulp preparations were all made from a single batch of wet pulp.

Weighed amounts of hay were hand-fed twice daily after milking in individual stanchions, with 2 hr being allowed for eating at each time. The barley and the beet pulps were fed twice daily in the milking barn. A representative sample of each feed was obtained at each feeding and composited for weekly dry matter determinations and for proximate analyses for each period. The proximate analyses of the feedstuffs are listed in Table 1.

The milk produced was weighed at each milking and a representative sample withdrawn and composited for weekly determination of milk fat by the Babcock procedure and of solids-not-fat by the Golding bead method.

A single sample was obtained at random from one day's production of each cow during each period for determination of heat of combustion of the milk solids. From these data the regression of energy value of milk solids on milk fat content was determined for use in calculating the energy production of the cows on the basis of the weekly milk analyses. Results of this procedure were virtually identical with those obtained using the following prediction equation devised by Lofgreen and Otagaki (7): $Y = 4.516 + 0.321X$, $Y$ being the combustion value of milk solids expressed as kcal per gram and $X$ being the milk fat per cent.

The cows were weighed immediately after milking, before being fed hay or allowed water, three days in succession each week during the entire trial. The average daily liveweight change of each cow was calculated for each period from the regression of weight on time.

## RESULTS AND DISCUSSION

The pertinent data regarding feed intake, milk production, and liveweight changes in Trials A and B are summarized in Tables 2 and 3, respectively.

The response to treatments in the two trials were comparable. In each case daily milk production was reduced by 5.0 lb when the basal ration was restricted, but there were no significant differences among the full-fed rations. The per cent milk fat was not affected, while solids-not-fat were decreased significantly on the restricted basal rations, as would be expected with the restricted energy intake.

The loss of weight on restricted basal was

TABLE 2

Feed intakes, amount and composition of milk produced and liveweight changes, Trial A

| | Restricted basal | Full basal | Restricted basal + barley | Restricted basal + B.P. | $S_{\bar{X}}$ |
|---|---|---|---|---|---|
| Feed intake, dry matter *(pounds/day)* | | | | | |
| Alfalfa hay | 15.8 | 20.6 | 15.8 | 15.8 | ........ |
| Barley | 6.8 | 9.1 | 12.6 | 6.8 | ........ |
| Beet pulp | ...... | ...... | ...... | 5.8 | ........ |
| Total | 22.6 | 29.7 | 28.4 | 28.4 | ........ |
| Increment | ...... | 7.1 | 5.8 | 5.8 | ........ |
| Milk production *(pounds/day)* | 32.0[b] | 37.0[a] | 36.4[a] | 35.9[a] | 0.498 |
| Butterfat *(avg %)* | 3.50[a] | 3.45[a] | 3.42[a] | 3.43[a] | 0.064 |
| Solids-not-fat *(avg %)* | 8.42[b] | 8.79[a] | 8.80[a] | 8.75[a] | 0.065 |
| Milk energy *(mcal/day)* | 9.8 | 11.6 | 11.3 | 11.1 | ........ |
| Liveweight change *(pounds/day)* | −0.84[b] | 0.10[a] | 0.22[a] | 0.51[a] | 0.154 |

[a, b] Values with different superscripts are significantly different.

TABLE 3

Feed intakes, amount and composition of milk produced and liveweight changes in Trial B

| | Restricted basal | Full basal | Restricted basal + M.B.P. | Restricted basal + CSFBP | $S_{\bar{X}}$ |
|---|---|---|---|---|---|
| Feed intake, dry matter *(pounds/day)* | | | | | |
| Alfalfa hay | 15.0 | 19.8 | 15.0 | 15.0 | ........ |
| Barley | 6.5 | 8.6 | 6.5 | 6.5 | ........ |
| Molasses beet pulp | ...... | ...... | 5.3 | ...... | ........ |
| C.S.F. beet pulp | ...... | ...... | ...... | 5.3 | ........ |
| Total | 21.5 | 28.4 | 26.8 | 26.8 | ........ |
| Increment | ...... | 6.9 | 5.3 | 5.3 | ........ |
| Milk production *(pounds/day)* | 29.9[b] | 34.9[a] | 34.1[a] | 33.7[a] | 0.519 |
| Butterfat *(avg %)* | 3.42[a] | 3.38[a] | 3.29[a] | 3.39[a] | 0.046 |
| Solids-not-fat *(avg %)* | 8.47[b] | 8.71[a] | 8.62[a, b] | 8.71[a] | 0.069 |
| Milk energy *(mcal/day)* | 9.1 | 10.7 | 10.3 | 10.4 | ........ |
| Liveweight change *(pounds/day)* | −0.78[b] | −0.02[a] | 0.49[a] | 0.30[a] | 0.188 |

[a, b] Values with different superscripts are significantly different.

comparable in both trials. Liveweight gains on the full-fed rations, although rather variable, were not significantly different from one another within trials, and averaged 0.28 and 0.26 lb per day in Trials A and B, respectively.

It is quite clear from these data that the barley and each of the three types of beet pulp, when added to the restricted basal ration, were equally efficient in restoring milk production and liveweight gains. While increments of 5.8 and 5.3 lb of dry matter, respectively, in Trials A and B restored 5.0 lb of milk, the energy content of the milk in Trial B was slightly lower. In Trial A the average difference in daily milk energy between the restricted basal and full-fed rations was 1.5 mcal, which is equivalent to 259 kcal per pound of barley and beet pulp increment. In Trial B the average difference between the restricted and full-fed rations was 1.4 mcal, or 264 kcal per pound of MBP and CSFBP increment, which is essentially of the same magnitude as that observed in the first trial.

These observations are in agreement with other work, both with lactating cows and fattening meat animals. Billings (2) demonstrated that plain and molasses beet pulps were of equal value in milk production rations. Other workers (3, 5) have shown that both types of beet pulp have been comparable to grains in milk production value when fed up to 60% of the concentrate mixture.

Holden (4) and Maynard and co-workers (9) found no effect upon the performance of fattening lambs when one-half of the corn was replaced with either plain or molasses dried beet pulp. Singleton et al. (10) found molasses beet pulp to be worth 97 to 111% of barley when fed at various levels up to 50% of fattening rations for cattle.

Recently, Lofgreen et al. (6) reported that for steers CSF beet pulp had a lower net energy value than molasses beet pulp but, in this case, palatability problems were encountered. In the present study with lactating cows and lower levels of feeding CSF dried beet pulp, there were no problems with palatability.

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J. A. M. A.
April 17, 1948



THE JOURNAL OF THE
AMERICAN MEDICAL ASSOCIATION

## BAGASSE DISEASE OF THE LUNGS

Sugar cane from which the juice has been extracted is called bagasse. The product is stored in the open for months or years when it is broken, processed and pressed into various shapes for insulating building materials. The dust of the dried grass is an industrial hazard. The disease that follows its inhalation is known under the dubious name of bagasse or even more improperly, perhaps, as bagassosis[1] or bagasscosis.[2] Sodeman and Pullen[3] state that "Since the suffix 'osis' is properly added only to words formed from Greek roots and since we have as yet not been able to trace the term 'bagasse' to the Greek, we prefer the simple term 'bagasse disease of the lungs."

Bagasse disease of the lungs is characterized by cough, dyspnea and hemoptysis, night sweats, chills and intermittent fever. Roentgenologic examination of the chest shows mottling of both lungs, like that of miliary tuberculosis. The disease commences insidiously. The pulmonary reactions incited by the inhalation of bagasse dust are reversible and complete resolution may occur. Because the disease is seldom fatal, only rare opportunities have thus far been presented to determine the histologic changes in the lungs.

Investigations of this sort have been limited to a single necropsy and to the removal of a few particles of tissue for biopsy, The lesions so far described consist of localized pneumonic areas composed of foam cells together with foreign body reactions around bagasse fibers.

The cause of bagasse disease is still obscure. Some investigators believe it is either a fungus or a bacterial infection, the causative agents being introduced on the surface of the inhaled dust. Others contend that it is a virus disease and still others that it is an allergic response to the presence of bagasse material.

Gerstl, Tager and Marinaro[4] have approached the subject experimentally and the results are suggestive. Suspensions of five lots of bagasse were administered intravenously, insufflated into the trachea or injected into the skin of rabbits and guinea pigs. Animals receiving intravenous injections of bagasse in suspension rapidly became ill or died. When, however, the dust was autoclaved similar amounts of the suspension could be given without apparent ill effects. The lungs and other viscera of the animals receiving fresh bagasse suspension showed extensive foci of necrosis and cellular reactions. In addition, the presence of mycelia and spores in the damaged organs served as an indication of the nature of the infective agent. Animals that received injections of autoclaved bagasse revealed only small granulomas in the lungs of the foreign body type. These results suggest that bagasse disease of the lungs is caused by a fungus and that the dust itself is relatively innocuous.

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